WRD RESOURCE ROOM NIMI

US Army Corps of Engineers
Omaha District

SEDIMENTATION NEAR THE CONFLUENCE OF THE MISSOURI AND NIOBRARA RIVERS 1954 TO 1990

NATIONAL PARK SERVICE
WATER RESOURCES DIVISION
FORT COLLINS, COLORADO
RESOURCE ROOM PROPERTY

Prepared by
Resource Consultants & Engineers, Inc.

Prepared for
River & Reservoir Engineering Section
Hydrologic Engineering Branch
Engineering Division
Omaha, Nebraska

Please do not remove
this item from
Resource Room

September 1992

M.R.D. Sediment Memoranda No. 12

U.S. ARMY ENGINEER DISTRICTS
OMAHA
KANSAS CITY

The Corps of Engineers Missouri River Basin sediment studies program was established for the development of practical sediment engineering for rational evaluation, regulation, and utilization of fluvial sediment phenomena. It was implemented as a comprehensive, basin-wide program for coordination of studies of sediment problems in the overall basin program for flood control and allied purposes as well as for continuity and perspective in the planning and design of individual projects. The program includes both investigations for the development of sediment transport theory and observations of existent and occuring phenomena for the purpose of developing the applications of theory to practical problems, developing empirical relationships and providing aids to judgement.

NATIONAL PARK SERVICE
WATER RESOURCES DIVISION
FORT COLLINS, COLORADO
RESOURCE ROOM PROPERTY

TABLE OF CONTENTS

SECTION I - INTRODUCTION I-1
1. Purpose I-1
2. Scope of Work I-1
3. Study area and Background Information I-2
4. History of Conditions Near the Missouri/Niobrara River Confluence I-3
5. Pertinent Data I-4

SECTION II - GAGING STATION TREND ANALYSIS II-1
1. Gaging Stations II-1
2. Rating Curves II-1
3. Common Discharges II-2
4. Trend Evaluation II-2

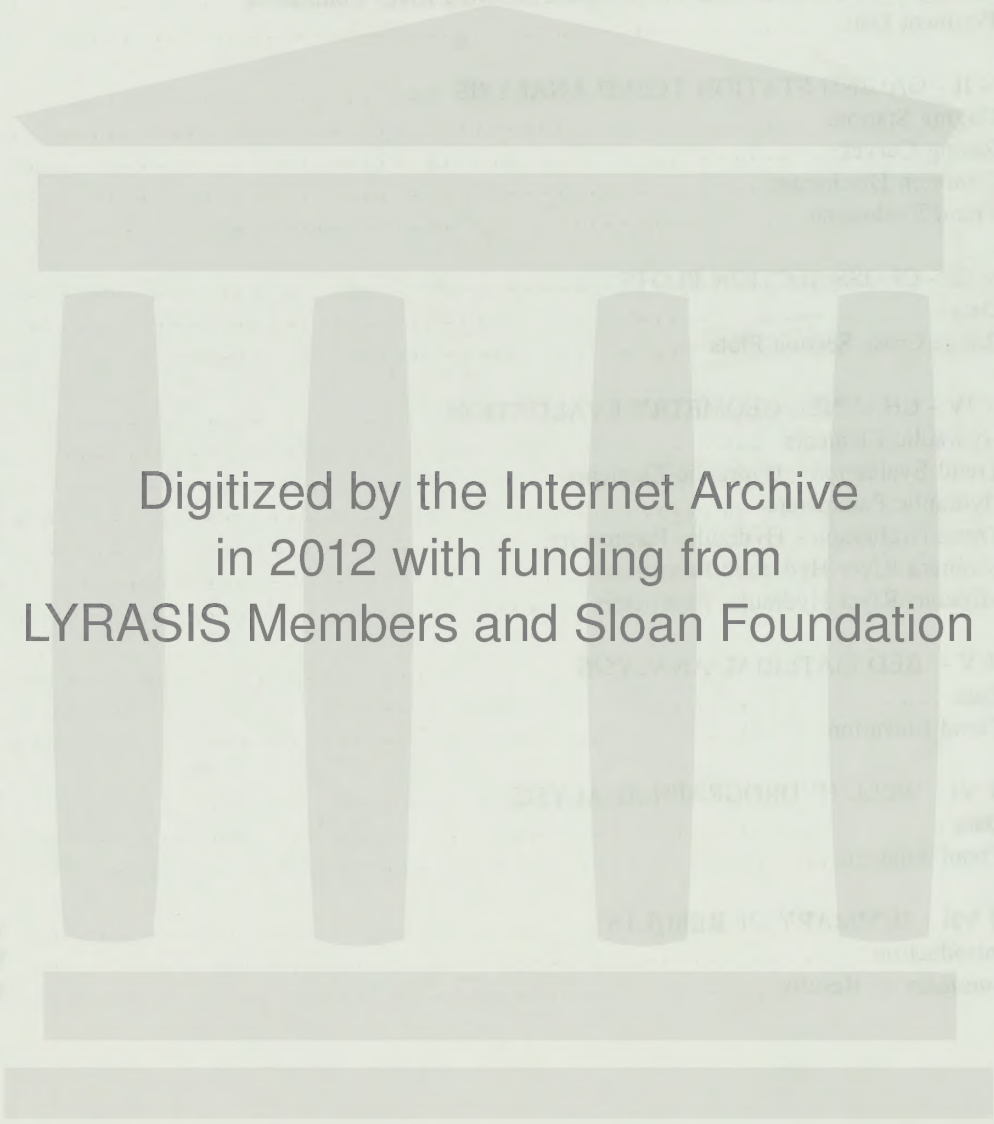
SECTION III - CROSS SECTION PLOTS III-1
1. Data III-1
2. Range Cross Section Plots III-1

SECTION IV - CHANNEL GEOMETRY EVALUATION IV-1
1. Hydraulic Elements IV-1
2. Trend Evaluation - Hydraulic Elements IV-1
3. Hydraulic Parameters IV-3
4. Trend Evaluation - Hydraulic Parameters IV-3
5. Niobrara River Hydraulic Parameters IV-3
6. Missouri River Hydraulic Parameters IV-4

SECTION V - BED MATERIAL ANALYSIS V-1
1. Data V-1
2. Trend Elevation V-1

SECTION VI - WELL HYDROGRAPH ANALYSIS VI-1
1. Data VI-1
2. Trend Analysis VI-1

SECTION VII - SUMMARY OF RESULTS VII-1
1. Introduction VII-1
2. Summary of Results VII-1



Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://archive.org/details/sedimentationnea00reso

APPENDIX TABLE OF CONTENTS

APPENDIX I - AVAILABLE DATA AND LOCATION MAPS

Table I.1. Existing stage discharge curves

Table I.2. Discharge data, Niobrara and Missouri Rivers

Table I.3. Range cross section and hydraulic elements data

Table I.4. Reference plane elevations

Table I.5. Bed material sediment data

Plate I-1. Study reach and gage station locations

Plate I-2. Range location map

Plate I-3. Niobrara Townsite groundwater piezometer well location map

Plate I-4. Niobrara River groundwater piezometer well location map

Plate I-5. Missouri River groundwater piezometer well location map

Plate I-6. Monthly reservoir release Fort Randall Dam.

Plate I-7. End of month pool elevations Lewis and Clark Lake.

APPENDIX II - RATING CURVE TREND PLOTS

Plate II-1. Niobrara River flow rating curve trend analysis, Highway #12, RM 1.3

Plate II-2. Niobrara River flow rating curve trend analysis, Verdel, RM 12

Plate II-3. Missouri River flow rating curve trend analysis, Niobrara, 1960 RM 842.9

Plate II-4. Missouri River flow rating curve trend analysis, Verdel, 1960 RM 846.5

Plate II-5. Missouri River flow rating curve trend analysis, Greenwood, SD

APPENDIX III - CHANNEL CROSS SECTIONS

Plate III-1. Niobrara River channel cross sections, Range 0.0, Years 1956, 1960, 1965, 1970, 1975.

Plate III-2. Niobrara River channel cross sections, Range 0.1, Years 1961, 1965, 1970, 1975.

Plate III-3. Niobrara River channel cross sections, Range 0.5, Years 1950, 1960, 1965.

Plate III-4. Niobrara River channel cross sections, Range 0.5, Years 1956, 1970, 1975, 1983.

Plate III-5. Niobrara River channel cross sections, Range 0.8, Years 1956, 1960, 1965.

Plate III-6. Niobrara River channel cross sections, Range 0.8, Years 1956, 1970, 1975, 1983.

Plate III-7. Niobrara River channel cross sections, Range 1.1, Years 1956, 1960, 1965.

Plate III-8. Niobrara River channel cross sections, Range 1.1, Years 1956, 1970, 1975, 1983.

Plate III-9. Niobrara River channel cross sections, Range 1.4, Years 1956, 1960, 1965.

Plate III-10. Niobrara River channel cross sections, Range 1.4, Years 1956, 1970, 1975, 1983.

Plate III-11. Niobrara River channel cross sections, Range 1.9, Years 1961, 1965, 1970.

Plate III-12. Niobrara River channel cross sections, Range 1.9, Years 1961, 1975, 1983.

Plate III-13. Niobrara River channel cross sections, Range 2.4, Years 1956, 1960, 1965.

Plate III-14. Niobrara River channel cross sections, Range 2.4, Years 1956, 1970, 1975, 1983.

Plate III-15. Niobrara River channel cross sections, Range 3.0, Years 1961, 1965, 1970.

Plate III-16. Niobrara River channel cross sections, Range 3.0, Years 1961, 1975, 1983.

Plate III-17. Niobrara River channel cross sections, Range 3.6, Years 1956, 1960, 1965.

Plate III-18. Niobrara River channel cross sections, Range 3.6, Years 1956, 1970, 1975, 1983.

Plate III-19. Niobrara River channel cross sections, Range 4.0, Years 1961, 1965, 1970.

Plate III-20. Niobrara River channel cross sections, Range 4.0, Years 1961, 1975, 1983.

Plate III-21. Niobrara River channel cross sections, Range 4.4, Years 1956, 1960, 1965.

Plate III-22. Niobrara River channel cross sections, Range 4.4, Years 1956, 1970, 1975, 1983.

Plate III-23. Niobrara River channel cross sections, Range 5.2, Years 1956, 1960, 1965.

Plate III-24. Niobrara River channel cross sections, Range 5.2, Years 1956, 1970, 1975, 1983.

Plate III-25. Niobrara River channel cross sections, Range 6.0, Years 1983.

Plate III-26. Niobrara River channel cross sections, Range 6.9, Years 1956, 1960, 1965.

Plate III-27. Niobrara River channel cross sections, Range 6.9, Years 1956, 1970, 1975, 1983.

Plate III-28. Niobrara River channel cross sections, Range 8.0, Years 1983.

Plate III-29. Niobrara River channel cross sections, Range 9.0, Years 1956, 1960, 1965

Plate III-30. Niobrara River channel cross sections, Range 9.0, Years 1956, 1970, 1975, 1983.

Plate III-31. Niobrara River channel cross sections, Range 10.5, Years 1983.

Plate III-32. Niobrara River channel cross sections, Range 11.6, Years 1983.

Plate III-33. Niobrara River channel cross sections, Range 13.0, Years 1956, 1960, 1965.

Plate III-34. Niobrara River channel cross sections, Range 13.0, Years 1956, 1970, 1975, 1983.

Plate III-35. Niobrara River channel cross sections, Range 13.8, Years 1983.

Plate III-36. Niobrara River channel cross sections, Range 14.5, Years 1983.

Plate III-37. Missouri River channel cross sections, Range 881.4, Years 1954, 1960, 1965.

Plate III-38. Missouri River channel cross sections, Range 881.4, Years 1954, 1970, 1975.

Plate III-39. Missouri River channel cross sections, Range 881.4, Years 1954, 1979, 1985.

Plate III-40. Missouri River channel cross sections, Range 882.0, Years 1954, 1960, 1965.

Plate III-41. Missouri River channel cross sections, Range 882.0, Years 1954, 1970, 1975.

Plate III-42. Missouri River channel cross sections, Range 882.0, Years 1954, 1979, 1985.

Plate III-43. Missouri River channel cross sections, Range 882.6, Years 1954, 1960, 1965.

Plate III-44. Missouri River channel cross sections, Range 882.6, Years 1954, 1970, 1975.

Plate III-45. Missouri River channel cross sections, Range 882.6, Years 1954, 1979, 1985.

Plate III-46. Missouri River channel cross sections, Range 883.3, Years 1954, 1960, 1965.

Plate III-47. Missouri River channel cross sections, Range 883.3, Years 1954, 1970, 1975.

Plate III-48. Missouri River channel cross sections, Range 883.3, Years 1954, 1979, 1985.

Plate III-49. Missouri River channel cross sections, Range 883.9, Years 1954, 1960, 1965.

Plate III-50. Missouri River channel cross sections, Range 883.9, Years 1954, 1970, 1975.

Plate III-51. Missouri River channel cross sections, Range 883.9, Years 1954, 1979, 1985.

Plate III-52. Missouri River channel cross sections, Range 884.4, Years 1954, 1960, 1965.

Plate III-53. Missouri River channel cross sections, Range 884.4, Years 1954, 1970, 1975.

Plate III-54. Missouri River channel cross sections, Range 884.4, Years 1954, 1979, 1985.

Plate III-55. Missouri River channel cross sections, Range 885.1, Years 1954, 1960, 1965.

Plate III-56. Missouri River channel cross sections, Range 885.1, Years 1954, 1970, 1975.

Plate III-57. Missouri River channel cross sections, Range 885.1, Years 1954, 1979, 1985.

Plate III-58. Missouri River channel cross sections, Range 885.6, Years 1955, 1960, 1965.

Plate III-59. Missouri River channel cross sections, Range 885.6, Years 1955, 1970, 1975.

Plate III-60. Missouri River channel cross sections, Range 885.6, Years 1955, 1979, 1985.

Plate III-61. Missouri River channel cross sections, Range 886.8, Years 1954, 1960, 1965.

Plate III-62. Missouri River channel cross sections, Range 886.8, Years 1954, 1970, 1975.

Plate III-63. Missouri River channel cross sections, Range 886.8, Years 1954, 1979, 1985.

Plate III-64. Missouri River channel cross sections, Range 888.9, Years 1955, 1960, 1965.

Plate III-65. Missouri River channel cross sections, Range 888.9, Years 1955, 1970, 1975.

Plate III-66. Missouri River channel cross sections, Range 888.9, Years 1955, 1979, 1985.

APPENDIX IV - HYDRAULIC ELEMENT AND HYDRAULIC PARAMETER PLOTS

Plate IV-1. Niobrara River, hydraulic element trends, surface width, Range 0.0, years 1956 - 1975.

Plate IV-2. Niobrara River, hydraulic element trends, surface width, Range 0.1, years 1961 - 1975.

Plate IV-3. Niobrara River, hydraulic element trends, surface width, Range 0.5, years 1956 - 1975.

Plate IV-4. Niobrara River, hydraulic element trends, surface width, Range 0.8, years 1956 - 1975.

Plate IV-5. Niobrara River, hydraulic element trends, surface width, Range 1.1, years 1956 - 1975.

Plate IV-6. Niobrara River, hydraulic element trends, surface width, Range 1.4, years 1956 - 1975.

Plate IV-7. Niobrara River, hydraulic element trends, surface width, Range 1.9, years 1961 - 1975.

Plate IV-8. Niobrara River, hydraulic element trends, surface width, Range 2.4, years 1956 - 1975.

Plate IV-9. Niobrara River, hydraulic element trends, surface width, Range 3.0, years 1961 - 1975.

Plate IV-10. Niobrara River, hydraulic element trends, surface width, Range 3.6, years 1956 - 1975.

Plate IV-11. Niobrara River, hydraulic element trends, surface width, Range 4.0, years 1961 - 1975.

Plate IV-12. Niobrara River, hydraulic element trends, surface width, Range 4.4, years 1956 - 1975.

Plate IV-13. Niobrara River, hydraulic element trends, surface width, Range 5.2, years 1956 - 1975.

Plate IV-14. Niobrara River, hydraulic element trends, surface width, Range 6.0, year 1983.

Plate IV-15. Niobrara River, hydraulic element trends, surface width, Range 6.9, years 1956 - 1975.

Plate IV-16. Niobrara River, hydraulic element trends, surface width, Range 8.0, year 1983.

Plate IV-17. Niobrara River, hydraulic element trends, surface width, Range 9.0, years 1956 - 1975.

Plate IV-18. Niobrara River, hydraulic element trends, surface width, Range 10.5, year 1983.

Plate IV-19. Niobrara River, hydraulic element trends, surface width, Range 11.6, year 1983.

Plate IV-20. Niobrara River, hydraulic element trends, surface width, Range 13.0, years 1956 - 1975.

Plate IV-21. Niobrara River, hydraulic element trends, surface width, Range 13.8, year 1983.

Plate IV-22. Niobrara River, hydraulic element trends, surface width, Range 14.5, year 1983.

Plate IV-23. Missouri River hydraulic element trends, surface width, Range 881.4 years, 1956 - 1985.

Plate IV-24. Missouri River hydraulic element trends, surface width, Range 882.0, years, 1954 -1985.

Plate IV-25. Missouri River hydraulic element trends, surface width, Range 882.6, years, 1954 -1985.

Plate IV-26. Missouri River hydraulic element trends, surface width, Range 883.3, years, 1954 -1985.

Plate IV-27. Missouri River hydraulic element trends, surface width, Range 883.9, years, 1954 -1985.

Plate IV-28. Missouri River hydraulic element trends, surface width, Range 884.4, years, 1954 -1985.

Plate IV-29. Missouri River hydraulic element trends, surface width, Range 885.1 years, 1954 - 1985.

Plate IV-30. Missouri River hydraulic element trends, surface width, Range 885.6, years, 1955 -1985.

Plate IV-31. Missouri River hydraulic element trends, surface width, Range 886.8 years, 1954 - 1985.

Plate IV-32. Missouri River hydraulic element trends, surface width, Range 888.9 years, 1955 - 1985.

Plate IV-33. Niobrara River, hydraulic element trends, cross sectional area, Range 0.0, years 1956 - 1975.

Plate IV-34. Niobrara River, hydraulic element trends, cross sectional area, Range 0.1, years 1961 - 1975.

Plate IV-35. Niobrara River, hydraulic element trends, cross sectional area, Range 0.5, years 1956 - 1975.

Plate IV-36. Niobrara River, hydraulic element trends, cross sectional area, Range 0.8, years 1956 - 1975.

Plate IV-37. Niobrara River, hydraulic element trends, cross sectional area, Range 1.1, years 1956 - 1975.

Plate IV-38. Niobrara River, hydraulic element trends, cross sectional area, Range 1.4, years 1956 - 1975.

Plate IV-39. Niobrara River, hydraulic element trends, cross sectional area, Range 1.9, years 1961 - 1975.

Plate IV-40. Niobrara River, hydraulic element trends, cross sectional area, Range 2.4, years 1956 - 1975.

Plate IV-41. Niobrara River, hydraulic element trends, cross sectional area, Range 3.0, years 1961 - 1975.

Plate IV-42. Niobrara River, hydraulic element trends, cross sectional area, Range 3.6, years 1956 - 1975.

Plate IV-43. Niobrara River, hydraulic element trends, cross sectional area, Range 4.0, years 1961 - 1975.

Plate IV-44. Niobrara River, hydraulic element trends, cross sectional area, Range 4.4, years 1956 - 1975.

Plate IV-45. Niobrara River, hydraulic element trends, cross sectional area, Range 5.2, years 1956 - 1975.

Plate IV-46. Niobrara River, hydraulic element trends, cross sectional area, Range 6.0, year 1983.

Plate IV-47. Niobrara River, hydraulic element trends, cross sectional area, Range 6.9, years 1956 - 1975.

Plate IV-48. Niobrara River, hydraulic element trends, cross sectional area, Range 8.0, year 1983.

Plate IV-49. Niobrara River, hydraulic element trends, cross sectional area, Range 9.0, years 1956 - 1975.

Plate IV-50. Niobrara River, hydraulic element trends, cross sectional area, Range 10.5, year 1983.

Plate IV-51. Niobrara River, hydraulic element trends, cross sectional area, Range 11.6, year 1983.

Plate IV-52. Niobrara River, hydraulic element trends, cross sectional area, Range 13.0, years 1956 - 1975.

Plate IV-53. Niobrara River, hydraulic element trends, cross sectional area, Range 13.8, year 1983.

Plate IV-54. Niobrara River, hydraulic element trends, cross sectional area, Range 14.5, year 1983.

Plate IV-55. Missouri River hydraulic element trends, cross sectional area, Range 881.4 years, 1956 - 1985.

Plate IV-56. Missouri River hydraulic element trends, cross sectional area, Range 882.0, years, 1954 -1985.

Plate IV-57. Missouri River hydraulic element trends, cross sectional area, Range 882.6, years, 1954 -1985.

Plate IV-58. Missouri River hydraulic element trends, cross sectional area, Range 883.3, years, 1954 -1985.

Plate IV-59. Missouri River hydraulic element trends, cross sectional area, Range 883.9, years, 1954 -1985.

Plate IV-60. Missouri River hydraulic element trends, cross sectional area, Range 884.4, years, 1954 -1985.

Plate IV-61. Missouri River hydraulic element trends, cross sectional area, Range 885.1 years, 1954 - 1985.

Plate IV-62. Missouri River hydraulic element trends, cross sectional area, Range 885.6, years, 1955 -1985.

Plate IV-63. Missouri River hydraulic element trends, cross sectional area, Range 886.8 years, 1954 - 1985.

Plate IV-64. Missouri River hydraulic element trends, cross sectional area, Range 888.9 years, 1955 - 1985.

Plate IV-65. Niobrara River, hydraulic element trends, mean channel depth, Range 0.0, years 1956 - 1975.

Plate IV-66. Niobrara River, hydraulic element trends, mean channel depth, Range 0.1, years 1961 - 1975.

Plate IV-67. Niobrara River, hydraulic element trends, mean channel depth, Range 0.5, years 1956 - 1975.

Plate IV-68. Niobrara River, hydraulic element trends, mean channel depth, Range 0.8, years 1956 - 1975.

Plate IV-69. Niobrara River, hydraulic element trends, mean channel depth, Range 1.1, years 1956 - 1975.

Plate IV-70. Niobrara River, hydraulic element trends, mean channel depth, Range 1.4, years 1956 - 1975.

Plate IV-71. Niobrara River, hydraulic element trends, mean channel depth, Range 1.9, years 1961 - 1975.

Plate IV-72. Niobrara River, hydraulic element trends, mean channel depth, Range 2.4, years 1956 - 1975.

Plate IV-73. Niobrara River, hydraulic element trends, mean channel depth, Range 3.0, years 1961 - 1975.

Plate IV-74. Niobrara River, hydraulic element trends, mean channel depth, Range 3.6, years 1956 - 1975.

Plate IV-75. Niobrara River, hydraulic element trends, mean channel depth, Range 4.0, years 1961 - 1975.

Plate IV-76. Niobrara River, hydraulic element trends, mean channel depth, Range 4.4, years 1956 - 1975.

Plate IV-77. Niobrara River, hydraulic element trends, mean channel depth, Range 5.2, years 1956 - 1975.

Plate IV-78. Niobrara River, hydraulic element trends, mean channel depth, Range 6.0, year 1983.

Plate IV-79. Niobrara River, hydraulic element trends, mean channel depth, Range 6.9, years 1956 - 1975.

Plate IV-80. Niobrara River, hydraulic element trends, mean channel depth, Range 8.0, year 1983.

Plate IV-81. Niobrara River, hydraulic element trends, mean channel depth, Range 9.0, years 1956 -

Plate IV-81. Niobrara River, hydraulic element trends, mean channel depth, Range 9.0, years 1956 - 1975.

Plate IV-82. Niobrara River, hydraulic element trends, mean channel depth, Range 10.5, year 1983.

Plate IV-83. Niobrara River, hydraulic element trends, mean channel depth, Range 11.6, year 1983.

Plate IV-84. Niobrara River, hydraulic element trends, mean channel depth, Range 13.0, years 1956 - 1975.

Plate IV-85. Niobrara River, hydraulic element trends, mean channel depth, Range 13.8, year 1983.

Plate IV-86. Niobrara River, hydraulic element trends, mean channel depth, Range 14.5, year 1983.

Plate IV-87. Missouri River hydraulic element trends, mean channel depth, Range 881.4 years, 1956 - 1985.

Plate IV-88. Missouri River hydraulic element trends, mean channel depth, Range 882.0, years, 1954 -1985.

Plate IV-89. Missouri River hydraulic element trends, mean channel depth, Range 882.6, years, 1954 -1985.

Plate IV-90. Missouri River hydraulic element trends, mean channel depth, Range 883.3, years, 1954 -1985.

Plate IV-91. Missouri River hydraulic element trends, mean channel depth, Range 883.9, years, 1954 -1985.

Plate IV-92. Missouri River hydraulic element trends, mean channel depth, Range 884.4, years, 1954 -1985.

Plate IV-93. Missouri River hydraulic element trends, mean channel depth, Range 885.1 years, 1954 - 1985.

Plate IV-94. Missouri River hydraulic element trends, mean channel depth, Range 885.6, years, 1955 -1985.

Plate IV-95. Missouri River hydraulic element trends, mean channel depth, Range 886.8 years, 1954 - 1985.

Plate IV-96. Missouri River hydraulic element trends, mean channel depth, Range 888.9 years, 1955 - 1985.

Plate IV-97. Niobrara River hydraulic parameter trends thalweg elevation, 1956 to 1983.

Plate IV-98. Niobrara River hydraulic parameter trends thalweg elevation, 1956 to 1983 (RM 0 to RM 7.0) .

Plate IV-99. Niobrara River hydraulic parameter trends, average bed elevation, 1956 to 1983.

Plate IV-100. Niobrara River hydraulic parameter trends, channel topwidth 1956 to 1983 (RM 0 to RM 7.0).

Plate IV-101. Niobrara River hydraulic parameter trends, channel topwidth 1956 to 1983.

Plate IV-102. Niobrara River hydraulic parameter trends, channel depth 1956 to 1983.

Plate IV-103. Niobrara River hydraulic parameter trends, channel area 1956 to 1983.

Plate IV-104. Missouri River hydraulic parameter trends, thalweg elevation 1954 to 1985.

Plate IV-105. Missouri River hydraulic parameter trends, channel area 1954 to 1985.

Plate IV-106. Missouri River hydraulic parameter trends, average bed elevation 1954 to 1985.

Plate IV-107. Missouri River hydraulic parameter trends, channel topwidth 1954 to 1985.

Plate IV-108. Missouri River hydraulic parameter trends, channel depth 1954 to 1985.

APPENDIX V - BED SEDIMENT GRADATIONS

Plate V-1. Niobrara River bed material trends, 10% coarser grain size, 1957 to 1980.

Plate V-2. Niobrara River bed material trends, 35% coarser grain size, 1957 to 1980.

Plate V-3. Niobrara River bed material trends, 50% coarser grain size, 1957 to 1980.

Plate V-4. Niobrara River bed material trends, 65% coarser grain size, 1957 to 1980.

Plate V-5. Niobrara River bed material trends, 90% coarser grain size, 1957 to 1980.

Plate V-6. Missouri River bed material trends, 10% coarser grain size, 1957 to 1980.

Plate V-7. Missouri River bed material trends, 35% coarser grain size, 1957 to 1980.

Plate V-8. Missouri River bed material trends, 50% coarser grain size, 1957 to 1980.

Plate V-9. Missouri River bed material trends, 65% coarser grain size, 1957 to 1980.

Plate V-10. Missouri River bed material trends, 90% coarser grain size, 1957 to 1980.

APPENDIX VI - GROUNDWATER PIEZOMETER HYDROGRAPHS

Plate VI-1. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #01.

Plate VI-2. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #02.

Plate VI-3. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #03.

Plate VI-4. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #04.

Plate VI-5. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #05.

Plate VI-6. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #06.

Plate VI-7. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #07.

Plate VI-8. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #08.

Plate VI-9. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #09.

Plate VI-10. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #10.

Plate VI-11. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #11.

Plate VI-12. Niobrara River groundwater piezometer hydrograph, Niobrara townsite #12.

Plate VI-13. Niobrara River groundwater piezometer hydrograph, Niobrara townsite USGS #32-6-8dd.

Plate VI-14. Missouri River groundwater piezometer hydrograph, DH-83-01.

Plate VI-15. Missouri River groundwater piezometer hydrograph, DH-83-02.

Plate VI-16. Missouri River groundwater piezometer hydrograph, DH-83-03.

Plate VI-17. Missouri River groundwater piezometer hydrograph, DH-83-03A.

Plate VI-18. Missouri River groundwater piezometer hydrograph, DH-83-04.

Plate VI-19. Niobrara River groundwater piezometer hydrograph, DH-83-05.

Plate VI-20. Niobrara River groundwater piezometer hydrograph, DH-83-06.

Plate VI-21. Niobrara River groundwater piezometer hydrograph, DH-83-07.

Plate VI-22. Niobrara River groundwater piezometer hydrograph, DH-83-08.

SECTION I - INTRODUCTION

1. Purpose

1.1. The objective of this study is to document the effect of Lewis and Clark Lake and Fort Randall Dam releases on the Niobrara River in Nebraska. Aggradation on this tributary has produced higher stages for a given discharge, resulting in increased open flow flooding of overbank areas and possible increase in the magnitude and frequency of ice-affected flooding.

1.2. The study area includes the 14.5 mile reach of the Niobrara River upstream of the confluence with the Missouri River and the mainstem of the Missouri River from about 4.5 miles downstream to about 3.5 miles upstream of the confluence. The study also includes eighteen groundwater piezometers located in the town of Niobrara, along the study reach of the Niobrara River and along the Missouri River in a reach extending from approximately 14.5 to 18 miles upstream of the confluence. A map showing the location of the project area is presented in Figure 1.1.

1.3. This study was performed using existing data; no additional surveys or data development was undertaken for the study. The report includes plots of the pertinent data and analysis of the trends indicated by these plots. This information is presented in a format suitable for use in later studies to predict future conditions that may be expected in the study area.

2. Scope of Work

2.1. This study was completed under Indefinite Delivery Contract DACW45-90-D-0031 for Hydraulic Engineering Services between the Omaha District, Corps of Engineers and Resource Consultants, Inc. in Fort Collins, Colorado. The Omaha District Project Engineer was:

Mr. Michael Knofczynski, P.E.
Hydrologic Engineering Branch
Corps of Engineers, Omaha District
Omaha, Nebraska 68102-4978
(Telephone No. 402/221-4578)

The Project Manager for Resource Consultants, Inc. was Dr. Robert A. Mussetter, P.E.

2.2. The scope of work for the study consisted of the following tasks:

- Review all available data and background information and formulate a detailed outline for the report.
- Analyze changes in the rating curves at two stations on the Niobrara River (Highway 12 and Verdel) and three stations on the Missouri River (Niobrara, Verdel, and Greenwood). This was accomplished by plotting stage versus time at each for three common discharges.
- Evaluate changes in channel geometry at 22 cross sections on the Niobrara River

and 11 cross sections on the Missouri River. This was accomplished by (1) plotting the cross section data surveyed at approximately 5 year intervals from the mid-1950s through 1985, (2) plotting the channel width, mean depth and cross sectional area versus elevation for each of the cross sections in (1) above, and (3) plotting the average bed elevation, surface width, cross sectional area, and thalweg elevation versus distance along the channel based on a common reference plane.

- Analyze changes in bed material gradation with time by plotting the D_{10}, D_{35}, D_{50}, D_{65}, and D_{90} versus distance along the channel for samples collected between 1957 and 1980.
- Analyze changes in the groundwater table by plotting water level data at eighteen groundwater piezometers located along the study reach and in the town of Niobrara.
- Present a detailed discussion of the observed conditions and existing trends based on the above data.

3. Study area and Background Information

3.1. The study reaches discussed in this report include the Niobrara River from its confluence with the Missouri River (River Mile 0.0) upstream to River Mile (RM) 14.5 and the Missouri River from 1960 RM 840.0 (Range 881.4) to 1960 RM 847.3 (Range 888.9). The Niobrara River enters the Missouri River at approximately 1960 RM 844. The study also includes data from groundwater piezometers located in the town of Niobrara, along the study reach of the Niobrara River and along the Missouri River between 1960 RM 858 and 1960 RM 862. Figure 1.2 shows the location of the cross sections and Figures 1.3, 1.4, and 1.5 show the location of the groundwater piezometers analyzed in this study.

3.2. The drainage area of the Niobrara River at its mouth is approximately 13,150 square miles. The drainage area of the Missouri River at the Fort Randall Dam, which is located approximately 35 miles upstream of the mouth of the Niobrara River is approximately 263,500 square miles.

3.3. The Niobrara River Basin originates in the high plains of eastern Wyoming, extends through the Sand Hills and drops into the Missouri River Valley near Niobrara, Nebraska. The topography of the basin ranges from rather mild slopes in the upper reaches to steeper slopes toward the confluence with the Missouri River.

3.4. The Niobrara River Basin climate is semi-arid. Temperature extremes vary from -20 F to 110 F with an average annual temperature of approximately 65 F. The warmest months occur in July and August and the coldest months occur in January and February.

3.5. Annual precipitation in the basin ranges from 8 inches in the eastern plains of wyoming to 14 inches in the eastern reaches of the basin near the Missouri River confluence. The majority of the

rainfall occurs in May, June and July. Snowfall in the basin is rather uniform receiving approximately 35 inches annually.

3.6. Runoff in the Niobrara River Basin generally peaks during March, April, and May with spring thaw augmented by seasonal rainshowers. Average discharges during these three months are generally between 2,500 cfs and 5,000 cfs near Verdel, Nebraska. The discharges during the remaining months average between 1,500 cfs to 5,500 cfs at the same location.

4. History of Conditions Near the Missouri/Niobrara River Confluence

Fort Randall Dam, located on the Missouri River 35 miles upstream of the Niobrara River confluence was closed in 1952. Gavins Point Dam, located on the Missouri River 35 miles downstream of the Niobrara River confluence was closed in 1955. These dams have had significant influence on the regime of the river in the study reach.

The Niobrara River is a relatively steep stream and carries a large sediment load. Since the Missouri River typically has slower flow velocities and thus reduced capacity to transport sediment, a portion of the sediment load from the Niobrara River is deposited near the confluence, forming a delta. Prior to construction of the dams, the delta continued to encroach into the mainstem of the Missouri River until runoff conditions reached magnitudes sufficient to redistribute the deposited material downstream. During extreme floods, a significant portion of the delta would be removed. This occurred, for example, in 1952 during a flow estimated at 500,000 cfs on the Missouri River.

Since closure of the dams, the large seasonal variation in the discharges has been restricted. Monthly average daily releases from Fort Randall Dam are plotted on Plate 1.6. The plot indicates that the maximum monthly average daily releases during the runoff period ranged from 20,000 to 30,000 cfs from closure to the mid-1960's. Since that time, however, the maximum values appear to have increased significantly. These maximum average releases exceed 30,000 cfs most years with several years exceeding 40,000 cfs. It is interesting to note, however, that the maximum monthly average daily release since closure occurred in 1953, just after closure of the dam.

The recorded end-of-month maximum pool elevations for Lewis and Clark Lake, shown in Plate 1.7, compliment the trend of increased releases. The plot indicates that from 1965 to the present, the maximum monthly pool elevations have been generally higher than those from closure of the Gavins Point Dam to 1965.

Although the releases from the Fort Randall Dam have increased they are still much lower than the flows on the Missouri River prior to the closure of the dam. The lower flows resulting from closure of the dam has reduced the ability of the Missouri River flows to remove the delta that continues to form at the confluence. Several significant floods have occurred on the Niobrara River since 1955, contributing to the continued growth of the delta. A flood in excess of 40,000 cfs occurred in March 1960 and floods of about 25,000 cfs occurred in 1962 and 1964. These floods delivered large quantities of sediment to the mainstem of the Missouri. The 1960 flood is reported to have extended the delta some 2,200 feet into the Missouri River.

5. Pertinent Data

5.1. The majority of data utilized in this study was obtained directly from the Omaha District Corps of Engineers. These data include rating curves for two gaging stations on the Niobrara River (Highway 12 and Verdel) and three stations on the Missouri River (Niobrara, Verdel, and Greenwood). Survey data for a total of 33 ranges were obtained and analyzed, including 11 on the Missouri River and 22 on the Niobrara River. One of these ranges (Missouri River, Range 880.70) was subsequently removed from the trend analysis due to incomplete survey data. For the trend analysis on the 10 remaining Missouri River ranges, 7 cross sections from each range were available. These cross sections were surveyed between 1954 and 1985 at approximately 5-year intervals. The Niobrara River trend analysis included 12 ranges with 6 cross sections each and 10 ranges with fewer than 6 cross sections. Similar to the Missouri River ranges, the Niobrara River ranges were surveyed between 1955 and 1983, with most resurveys occurring at approximately 5 year intervals.

5.2. Piezometer data from 21 groundwater wells were available with which to construct groundwater piezometer hydrographs. Twelve of these wells are located within or directly adjacent to the Niobrara townsite; of the remaining 9, 5 are located adjacent to the Niobrara river upstream of Verdigre Creek, and 4 are adjacent to the Missouri River upstream of Niobrara.

5.3. Four years of bed material sediment gradation data from the Missouri River were obtained (1957, 1967, 1975, and 1980), and five years of sediment gradation data for the Niobrara River (1957, 1963, 1970, 1975, and 1980) were also available for analysis.

SECTION II - GAGING STATION TREND ANALYSIS

1. Gaging Stations

1.1. Data from five gaging stations in or near the study reach were analyzed for this study. Two of these gages are located on the Niobrara River, and three are located on the Missouri River. The location of these gages is shown on Plate I.1.

1.2. The Niobrara River gages include Niobrara River Near Verdel and Niobrara River at Highway #12. The Verdel gage is located 6.6 miles south of the town of Verdel, Nebraska, approximately 12 miles upstream of the mouth. The Highway #12 gage is located just west of the town of Niobrara, approximately 1.3 miles upstream of the mouth (Plate I.1). As of 1970, all records at Verdel and Niobrara were rated as poor (COE, 1970). The poor rating is due to the steep slope and shallow, braided nature of the river that results in continual channel shifting and modification of the stage discharge relationship. A USGS description of the Verdel gage from 1986 describes flow records as fair.

1.3. The Verdel gage was originally installed in April 1938 and relocated in 1939, 1940, and 1985. The 1939 relocation moved the gage 150 feet downstream. The 1940 relocation moved the gage to approximately its original location. In 1985, the gage was moved 2,600 feet upstream to its present location. The gage datum for the pre-1985 stations was 1,308.12 feet, which is 4.00 feet lower than that of the existing gage (1,312.12'). The Highway #12 bridge was rebuilt in 1978, at which time it was moved approximately 100 yards downstream towards the mouth of the Niobrara River.

1.4. The three Missouri River gages utilized in this study include the Missouri River near Verdel, the Missouri River at Niobrara, and the Missouri River at Greenwood, South Dakota. As of 1970, flow records for the Missouri River downstream of Fort Randall were rated as good (COE, 1970). The Missouri River near Verdel gage is located at RM 846.5 on the true right bank approximately 3 miles northwest of the town of Niobrara. The Missouri River at Niobrara gage is located at RM 844.4 approximately 1 mile downstream of the Niobrara River confluence. The Missouri River at Greenwood, South Dakota gage is currently located at RM 862.9 on the true left bank at Greenwood, South Dakota, approximately 20 miles upstream of the Niobrara River confluence.

1.5. The Greenwood gage on the Missouri River has been relocated three times. From May 1957 to September 1987 the gage was located at RM 865.0. The gage was moved between May 1988 and April, 1989, during which time period no rating curves were developed. In October 1989, the gage was moved to its present location at RM 862.9.

2. Rating Curves

2.1. Rating curves provided by the Omaha District Corps of Engineers were used to develop a gaging station trend analysis. The available rating curves are summarized in Table I.1. The rating curves provide measured stage/discharge points and an approximate curve representing the general stage/discharge relationship for each gage during a given time period. Interpolation of river stages for specific discharges on each rating curve allows the development of a stage trend through time at each gage.

2.2. The rating curve data at each gage are limited in that either rating curves for specific years are missing, or a single rating curve was used to represent the stage/discharge relationship over a period of several years (Table I.1). These data limitations are discussed in the trend evaluation (Section 3.4).

3. Common Discharges

3.1. The objective of the gage trend analysis is to compare sequential rating curves to determine the variation in stage for specific discharges through time. These discharges are referred to as common discharges and represent the normal range in flow at the gage. The common discharges established for this study are 1,000 cfs, 2,000 cfs, and 3,000 cfs for the two Niobrara River gages, and 20,000 cfs, 30,000 cfs, and 40,000 cfs for the three Missouri River gages. These common discharges were chosen in consultation with the Omaha District, U.S. Army Corps of Engineers project manager and generally represent the range of frequently occurring flows past the gages. Total annual inflow and peak discharges for the Missouri River at Fort Randall Dam and the Niobrara River near Verdel are summarized in Table I.2.

4. Trend Evaluation

4.1. The gaging station trend analysis consisted of determining stages corresponding to each of the common discharges from the rating curves and plotting those stages through time. The resulting plots of stage at the common discharges through time for each gage are shown on Plates II.1 through II.5 in Appendix II.

4.2. Niobrara River at Highway #12. The Niobrara River gage at Highway #12 depicts a significant increase in stage for the common discharges between 1965 and 1990(Plate II.2). There are significant limitations in the available data, however. The primary limitation is the lack of rating curves between 1978 and 1986; this time period is critical to the trend analysis because the gage was relocated in 1978 when the bridge was rebuilt approximately 100 yards downstream. The stage increased by approximately 1.6 feet during this time. The amount of increase in stage due to the gage relocation is unknown. It is unlikely that the 1.6 foot increase in stage between 1973 and 1985 was entirely the result of gage relocation since the gage was moved in a downstream direction, and a distance of only a few hundred feet. Consequently, significant aggradation probably occurred during this time period at the Highway #12 Bridge. (As will be discussed in a later section this conclusion is supported by the cross section surveys in this area). A long-term aggradation rate of approximately 0.1 to 0.15 ft/yr at Niobrara was predicted in 1970 (COE, 1970). Discounting possible effects of the gage relocation, the average rate of increase in stage at a discharge of 3,000 cfs between 1966 and 1986 is approximately 0.14 ft/yr. This suggests that the rates of channel aggradation at Niobrara are within the range of those predicted previously.

4.3. Niobrara River at Verdel. The stage trend for the Niobrara River near Verdel indicates a relatively constant stage/discharge relationship between 1938 and 1974 followed by an abrupt increase in stage after 1989 (Plate II.3). No data are available between 1974 and 1989. As previously discussed, the gage was moved 2600 feet upstream in 1985. Considering the gradient of the river in this reach of about 7 feet per mile, the relocation could result in an upward shift of approximately 3-1/2 feet. The stage trend,

therefore, indicates that the channel has not aggraded or degraded significantly during the period of record.

4.4. Since 1986, the stage has varied less than 0.5 feet for each of the common discharges. The stage at 1,000 cfs ranged from approximately 1,226.6 to 1,227.1 feet between 1986 and 1990. The predicted long-term average water surface elevation for 1,000 cfs at this site was estimated at 1,227.0 feet (COE, 1970).

4.5. The gage trends for both Niobrara River gages should be treated with some caution as the quality of data at both gages has been rated as poor (COE, 1970). More recently, the records for the Verdel gage have been described as fair (USGS, 1986).

4.6. Missouri River Gages. Three Missouri River gages were utilized in the trend analysis. The gage trend plots for these three gages are included as Plate II.3 through Plate II.5.

4.7. Missouri River at Niobrara. The Missouri River at Niobrara gage is located approximately 1 mile downstream of the Niobrara River confluence. This gage shows a general increase in stage for all three common discharges between 1955 and 1990 (Plate II.3). At a discharge of 20,000 cfs, the stage elevation increased approximately 6 feet during this time period at an average rate of 0.17 ft/yr. This stage increase in the Missouri River at Niobrara may reflect the continued growth of the Niobrara River delta. Episodic sediment deposition and delta growth at the confluence has resulted from the combination of delivery of large quantities of sediment by the Niobrara River and reduction of sediment transport capacity of the Missouri River due to flow control which began in the 1950s. The rate of stage increase has varied dramatically through the period of record. The most rapid increase in stage occurred between 1957 and 1960, when the stage for 30,000 cfs rose approximately 3 feet in 3 years, a rate of 1.0 ft/yr. This abrupt rise in stage occurred prior to and perhaps in part during a large flood in 1960 on the Niobrara River that exceeded 40,000 cfs. Numerous ice jams occurred during the flood which resulted in extensive deposition on the Niobrara River delta (COE, 1970). The gage trend analysis shows that between 1966 and 1977, the stage did not increase appreciably for any of the 3 common discharges. This suggests that during this time period, either: 1) relatively minor quantities of sediment were delivered by the Niobrara River; 2) flows released from Fort Randall Dam on the Missouri River were high enough to transport any delivered sediment beyond the delta area, or 3) the river was adjusting to sediment deposition that occurred during the 1960 flood. Total annual inflow volumes from the Missouri River at Fort Randall Dam gage (Table I.2)indicate that this time period was characterized by relatively high inflow.

4.8. Between 1978 and 1986 the stage increased by about 2.5 feet or an average rate of 0.3 feet/year. From 1986 to 1990, little overall change is indicated. For the period of record, the average rate of increase in stage was 0.17 feet/year. A long-term aggradation rate of 0.10 to 0.15 ft/yr was predicted for the Missouri River at Niobrara in 1970 (COE, 1970), which is somewhat less than actually occurred.

4.9. Missouri River Near Verdel. The Missouri River near Verdel gage, located approximately 5 miles upstream of the mouth of the Niobrara River, depicts a relatively constant stage for each common

discharge between 1968 and 1977, followed by an increase in stage of almost 4 feet between 1977 and 1990 (Plate II.4). This pattern is very similar to that of the Missouri River at Niobrara gage. The average rate of increase between 1977 and 1990 is approximately 0.30 ft/yr, which is a faster rate than that observed for the same time period at the Niobrara gage. This abrupt increase in stage reflects the upstream influence of the Niobrara River delta on Missouri River hydraulic conditions and sediment transport capacity. The continued growth of the Niobrara River delta has been related to the lack of high flow releases from Fort Randall Dam (COE, 1970). As the delta grows, it effectively blocks the channel and generates a backwater effect upstream. This results in a reduction in sediment transport capacity and bed aggradation.

4.10. Missouri River at Greenwood. The Missouri River at Greenwood gage, located approximately 20 miles upstream of the Niobrara River confluence, shows no consistent change in stage with time (Plate II.5). The stages for each of the common discharges have not changed more than 1 foot between 1960 and 1990. In contrast to the Missouri River gage near Verdel, this gage is located upstream of any significant influence of the Niobrara River.

SECTION III - CROSS SECTION PLOTS

1. Data

1.1. The channel cross section data available for this study are listed in Table I.3. The locations of channel cross sections are shown on **Plate I.2**. Of the 33 ranges considered in this study, ten are on the Missouri River, and 22 are on the Niobrara River. Data for the Missouri River ranges consist of 6 cross sections at each range between 1954 and 1985, resurveyed at approximately 5-year intervals. Of the 22 Niobrara River ranges, 12 were resurveyed 6 times between 1955 and 1983 at approximate 5-year intervals; the remaining 10 were resurveyed less frequently, several having only one survey in 1983.

1.2. The Missouri River range numbering system is based on 1941 River Miles. In 1960, the river mile reference for the Missouri River was changed. Consequently, Missouri River range numbers do not correspond to post-1960 river mile locations. Both range number and 1960 river mile locations are provided on the range plots for clarification.

2. Range Cross Section Plots

2.1. The cross section plots utilized in this study are compiled in Appendix III as Plates III.1 through III.66. Several years of cross section data were available for each range. In order to maximize clarity, individual ranges are commonly represented by a series of plots, each of which contain 3 to 4 cross sections. In these cases, where multiple plots are presented for a single range, the cross section from the original survey is repeated on each plot to maintain a general reference baseline for ease of comparison.

2.2. The lateral limits of the cross section plots reflect the limits of the available data. Some of the cross sections at a single range cover only the main channel, whereas longer sections at the same range may traverse large segments of the adjacent floodplain. All of the sections run at least across the channel from bank to bank, so that the net change within the channel is well documented.

SECTION IV - CHANNEL GEOMETRY EVALUATION

1. Hydraulic Elements

1.1. The hydraulic element analysis consisted of evaluating changes in channel width, mean channel depth, and cross sectional area with elevation for each cross section. Plates IV.1 through IV.96 contain hydraulic element plots for each range. The data used to construct these plots were retrieved from hydraulic element tables provided by the U.S. Army Corps of Engineers, Omaha District. These tables contain the values of each hydraulic element variable at 1 foot elevation intervals, allowing the determination of vertical trends for each element at the cross section. The channel width values represent the total channel topwidth of the surveyed section at each elevation interval. Cross section area values represent the area within the channel below each elevation increment. Mean channel depth is an index that was derived by dividing channel area by width at each elevation.

1.2. Because of the manner in which the hydraulic elements values were computed, the value of certain portions of these plots is limited. When the reference interval is lower than the floodplain bordering the channel, the plots accurately represent the trends within the bank-to-bank channel. When the reference elevation is higher than the floodplain, however, the portion of the surveyed cross section beneath the reference elevation on the floodplain is included in the hydraulic element calculations and therefore influences the trend indicated on the plots. This is easily identified on the plots as an abrupt increase in width and/or reduction in average channel depth with increasing elevation. This must be considered in interpreting the trends indicated on the hydraulic element plots.

2. Trend Evaluation - Hydraulic Elements

2.1. Plots of the variation in cross sectional area, channel width, and mean depth with elevation at all ranges considered in this study are included in Appendix IV as Plate IV.1 through Plate IV.96. Four ranges representative of the typical conditions in the study reach have been selected for discussion. The first two of these ranges are from the Missouri River, one located upstream of the Niobrara River confluence and the other downstream. The third is from the Niobrara River near the mouth, and the fourth is from the upstream portion of the Niobrara River study reach. Trends similar to those discussed below can be seen for the remainder of the ranges by studying Plate IV.1 through Plate IV.96.

2.2. Niobrara River Range N 0.0 (Plates IV.1, IV.33, IV.64). Plate IV.33 shows the channel area hydraulic element plot for Niobrara Range 0.0, located at the mouth of the Niobrara River. The plot indicates a loss of cross sectional area in the lower 6 feet of the channel, below elevation 1,218. The mean depth plot (Plate IV.64) shows that the channel infilling occurred below the elevation of 1,220 feet. Plate IV.1 contains the mean channel width and shows that the lower channel section has narrowed significantly. Only the bed of the Niobrara River has been affected at this location; apparently, no significant bank erosion has occurred since 1956. Delta development and growth has been characterized by general aggradation and reduction of mean channel depth and cross sectional area, without extensive lateral erosion and channel migration.

2.3. Niobrara River Range N 9.0 (Plates IV.17, IV.49, and IV.81). The channel changes at

Range 9.0 have primarily occurred in the channel bottom. Deposition within the relatively wide, shallow channel has resulted in a net loss of cross section area since 1956. Although the relative reduction in channel cross section at this location is less than at Range 0.0, the data suggests that the effects of sedimentation problems at the mouth of the Niobrara River extend upstream at least to RM 9. The only cross section upstream of RM 9 for which such a comparison can be made is located at Range 13.0. The data at this location indicates no progressive reduction in channel area (Plate IV.52).

2.4. Missouri River Range 883.3 (Plates IV.26, IV.58 and IV.90). This range is located at 1960 RM 841.9, approximately 2 miles downstream of the Niobrara River confluence. The hydraulic elements plot for cross sectional area (Plate IV.58) shows channel infilling in the lower part of the section. Above elevation 1,210 feet, channel area increases with elevation at the same rate, suggesting that the entire change in channel area occurred in the lowermost 10 feet of the cross section. A hydraulic element plot for channel width at Range 883.3 (Plate IV.26) shows some channel narrowing in the lower section and relatively little change in the upper section. The mean depth hydraulic element plot for Range 841.9 (Plate IV.86) shows the infilling of a relatively deep channel section present in 1954. The mean channel depth decreased approximately 10 feet between 1954 and 1985.

2.5. Missouri River Range 885.6 (Plates IV.30,IV.62, IV.94). Range 885.6 is located at RM 844.1, just upstream of the Niobrara River confluence. The channel area plot (Plate IV.62) shows channel infilling in the lower 15 feet of the section, from elevation 1,195 to elevation 1,210. The 1970 line shows an increase in channel area in the lower part of the section, reflecting a period of channel incision between 1965 and 1970. Above this elevation, little apparent change in cross section area has occurred since 1955. The mean depth plot (Plate IV.94) shows that in the lower part of the section, mean depth decreased between 1955 and 1965, and then abruptly increased by 1970. This reflects rapid channel incision between 1965 and 1970 to a thalweg elevation that was lower than the original 1955 thalweg elevation. The channel width plot (Plate IV.62) shows an increase in channel width between 1955 and 1985 for the majority of the section, which reflects bank erosion and channel widening during this time period.

3. Hydraulic Parameters

3.1. Hydraulic parameters evaluated in this study include channel width, cross sectional area, mean depth, average bed elevation and thalweg elevation. The objective of the hydraulic parameter trend analysis is to evaluate changes in parameters spatially and temporally by plotting the parameters versus station for each year of available data. The parameters were determined at each range in relation to a consistent elevation increment so that they could be compared throughout the study reach. The chosen elevation increment is referred to as a reference plane. The objective of defining a reference plane is to provide a datum at each range that encompasses all changes that occurred in the cross section area over the period of record. The reference planes were developed in this study by determining the maximum elevation of channel changes at each range and plotting these elevations as a profile. A reference plane profile composed of straight line segments was then developed that approximately paralleled the bed profile and encompassed all of the channel changes. Where the reference plane elevation is greater than the floodplain elevation, caution must be used when interpreting hydraulic parameter plots, as floodplain areas are included in the calculations. In addition, at some cross sections the reference plane elevation is above all surveyed points in the cross section. The reference plane elevation chosen for each range are summarized in Table I.3. The hydraulic parameters shown in Plate IV.97 through Plate IV.108 were taken from the hydraulic element tables for the reference plane elevation.

4. Trend Evaluation - Hydraulic Parameters

4.1. Each data point utilized in the hydraulic parameter trend analysis represents a single river cross section at a single point in time. Due to the inherent lateral and temporal variability in cross section size and shape, the representation of a river reach by a single section is tenuous. Consequently, the hydraulic parameter trends should be evaluated as general trends, and single anomalous points should be interpreted with caution.

5. Niobrara River Hydraulic Parameters

5.1. Hydraulic parameter trend plots for the Niobrara River are included in Appendix IV.

5.2. Thalweg Elevation. Two thalweg elevation plots are presented for the Niobrara River study reach. Plate IV.97 shows the entire approximately 14 mile study reach; Plate IV.98 shows the lower 7 miles only. The plots contain individual thalweg profiles from 1956, 1960, 1965, 1970, 1975 and 1983 (Plate IV.97). These profiles are roughly parallel and relatively smooth from the upstream study limit downstream to RM 7. A comparison of the 1975 and 1983 thalweg profiles shows an increase in thalweg elevation at RM 12 near the Verdel gage during that time period. Consequently, the thalweg profiles corroborate the gage trends at the Verdel gage.

5.3. Downstream of RM 7.0, the thalweg profiles are much more irregular, reflecting the episodic nature of deposition related to the Niobrara River delta. Although areas of deposition have shifted through time, a net aggradational trend is present between the mouth of the Niobrara River and RM 7.0.

5.4. Average Bed Elevation. Average bed elevation plots for the entire Niobrara River study reach and the lower 7 miles, only, are presented in Plate IV.99 and IV.100. Whereas thalweg profiles represent the lowest elevation in a cross section, the average bed elevation is determined by dividing the channel area beneath the reference plane by the channel width. This helps to remove the effects of local variations in thalweg elevation that may occur in a single cross section which are independent of any regional trends. As expected, the average bed elevations determined from a common reference plane display much less variability than the thalweg elevations. The average bed elevation profiles are generally within a few feet of each other for the upstream portion of the study reach; no trends can be discerned from the plot. Between RM 5 and RM 7, an aggradational trend is present which depicts a net increase of average bed elevation of approximately 3 feet between 1956 and 1983. The profiles diverge in the lower part of the study reach, from approximately RM 2 downstream, and an increase in average bed elevation of approximately 5 feet is present at the mouth of the river.

5.5. Channel Topwidth. Plate IV.99 shows a gradual increase in topwidth downstream through the study reach to approximately RM 1, followed by an abrupt channel narrowing downstream to the mouth. In general, topwidths have not varied in any consistent manner through time. The relatively narrow 1983 sections represent data available for that year, rather than a narrowing trend through time.

5.6. Channel Depth. Plate IV.100 shows channel depth relative to a common reference plane for the Niobrara River ranges. Similar to channel width, channel depth increases in the downstream direction for a given year. Upstream of approximately RM 9, channel depth decreased continually between 1956 and 1975. This reduction was relatively minor, on the order of 0.2 to 0.4 feet. Downstream of RM 9, the reduction in depth through time is much more dramatic. Between RM 9 and RM 0, the reduction in depth at a common reference plane has averaged approximately 2 feet between 1956 and 1983. The most dramatic loss of depth has been at the mouth of the river, where there has been over 4 feet of depth reduction since 1956.

5.7. Channel Area. The hydraulic parameter trend analysis for channel area is shown on Plate IV.101. The channel area trend is similar to the depth trend, in that the most dramatic reduction in channel area has occurred downstream of RM 9.0. Upstream, the loss of channel area has been relatively minor. Approximately 5,000 square feet of channel area reduction beneath the reference plane has occurred from RM 9.0 to the mouth between 1956 and 1983. This loss of channel area has been most dramatic downstream of RM 1, where over 10,000 square feet of channel area has been lost.

6. Missouri River Hydraulic Parameters

Hydraulic parameter trend plots for the Missouri River study reach are included in Appendix IV.

6.1. Thalweg Profiles. Plate IV.102 shows thalweg profiles for the Missouri River study reach. The profiles show tremendous local variability in thalweg elevation. Upstream of the Niobrara River confluence (approximately RM 844), the thalweg profiles from 1960, 1965, and 1970 show thalweg deepening on the order of 10 feet relative to the 1954 and 1975 profiles. The deepening is represented by

a single data point and therefore cannot be used to suggest a regional trend. In general, there is no apparent trend of rising or lowering thalweg elevation through time on the Missouri River study reach.

6.2. Average Bed Elevation. The average bed elevation is determined by dividing the channel area beneath the reference plane by the channel width, so that the effects of local variations in thalweg elevation are reduced. Plate IV.103 shows the average bed elevation profiles for the Missouri River study reach. Whereas the thalweg profiles showed no apparent general trends, the average bed elevation trends are very clear. The average bed elevation has increased throughout the study reach between 1954 and 1985. Upstream of the Niobrara River confluence, at approximately RM 843.9, the increase in bed elevation has been approximately 2 feet between 1954 and 1985. For the same time period downstream of the confluence, the rise in average bed elevation has ranged between 2 feet and 6 feet. This rise downstream of the confluence probably reflects downstream redistribution of Niobrara River sediment by the Missouri River and may reflect some additional growth of the Niobrara River delta. The plot also shows that since 1954, the average bed elevation profile has smoothed somewhat downstream of the confluence, which probably also reflects the downstream reworking of sediment delivered by the Niobrara River.

6.3. Channel Topwidth. Plate IV.104 shows channel topwidth trends for the Missouri River study reach. Topwidths are measured as the width of the chosen reference plane. Topwidths on the Missouri River are highly variable spatially, but have remained relatively constant through time. This maintenance of channel topwidth suggests that delta development at the mouth of the Niobrara River has not caused significant lateral destabilization of the Missouri River. Where the reference plane elevation is higher than the floodplain, however, channel topwidth may be poorly represented in the hydraulic parameter plots. As depicted on the cross section plots, some bank erosion has occurred at Missouri River Ranges 883.9 and 884.4 (Plates III.49 to III.51, Plates III.52 to III.54).

6.4. Channel Depth. Channel depth relative to the common reference plane for the Missouri River is shown on Plate IV.105. There has been an overall reduction in channel depth between 1954 and 1984 in the study reach. This reduction in depth is commensurate with the increase in average bed elevation discussed in Section 4.4.2.2. The loss of channel depth has been most dramatic downstream of the Niobrara River confluence, where 3 to 5 feet of depth reduction has occurred. At some locations, the channel depth has been reduced by almost 50% since 1954. The loss of channel depth upstream of the confluence averages approximately 2 feet, or about 25% of the total channel depth.

6.5. Channel Area. The channel area trends for the Missouri River study reach are shown on Plate IV.106. A general trend of decreasing channel area is present for the entire study reach between 1954 and 1985. The most significant loss in channel area has been downstream of the Niobrara River confluence, where up to 40% of channel area has been lost (e.g. Range 882.6). Upstream of the confluence, a reduction of approximately 20% of the channel area has occurred (e.g. Range 886.8).

SECTION V - BED MATERIAL ANALYSIS

1. Data

1.1. Bed material sediment data utilized in this study was provided from the Omaha District, U.S. Army Corps of Engineers. The data are presented in terms of percent coarser; that is, the grain size for which a given percent of the sample by weight is coarser. For example, a 10% coarser grain size of 2mm means that 10% of the sediment sample by weight is coarser than 2mm. Large variations in sediment gradations occur naturally in river systems; different geomorphic features within a channel (e.g. bed, bars, crossings, pools, etc..) will be characterized by very different grain sizes. The data provided describe the samples as bed material, however the actual locations of sampling are unknown with respect to channel geometry. Consequently, the data should be evaluated in terms of general trends, and limited emphasis should be placed on outliers. Tables and plots of the bed sediment data are contained within Appendix V.

2. Trend Elevation

2.1. The Niobrara River sediment size data are shown in Table VI.1 and Plates V.1 through V.5. The coarse fraction (10% coarser) of the Niobrara River sediment is composed of medium to coarse sand (Plate V.6). The 50% coarser fraction is composed of fine to medium sand (Plate V.8), whereas the fine fraction (90% coarser) sediment is dominated by fine grained sand (Plate V.10). These sediment gradations are similar to those of the Missouri River. The trends show a slight reduction in sediment grain size in a downstream direction; this fining is probably the result of deposition of fine sediment at the mouth of the Niobrara caused by backwater conditions generated at the confluence. No significant coarsening or fining trends through time are apparent from the Niobrara River bed sediment data.

2.2. Missouri River bed sediment plots are shown in Table VI.2 and Plates V.6 through V.10. Four years of sediment data were available including 1957, 1967, 1975 and 1980. Plates V.1 through V.5 show 10%, 35%, 50%, 65% and 90% coarser gradations for the available data, respectively. The 10% coarser grain size plot (Plate V.6) represents the coarse fraction of the bed sediment. This sediment is generally composed of coarse-grained sand, reflecting the sand-dominated nature of the Missouri River sediment. Two samples contained fine gravel-size sediment in the 10% coarser fraction. No general trends are apparent in terms of consistently changing grain size either spatially or temporally. **

2.3. The 50% coarser sediment size for the Missouri River bed sediment data (Plate V.8) is entirely composed of medium sand. The 90% coarser sediment is composed of fine sand (Plate V.5). Based on the 1975 data set which is the most complete, both the 90% coarser and, to a lesser extent, the 50% coarser trends depict slight increasing grain size trends in the downstream direction. The increase in the 90% coarser size fraction occurs abruptly at the Niobrara River confluence.

2.4. The bed sediment gradation plots indicate that the fine fraction of Missouri River bed sediment is slightly coarsened by Niobrara River input, however the coarsest (10%) fraction is relatively unaffected. This correlates with the Niobrara River gradation data which indicate that the Niobrara River contributes primarily medium to coarse grained sand to the Missouri River system. The Missouri River is dominated by sand-size sediment. The effect of Niobrara River sediment contribution on grain size is a slight coarsening of the fine sand fraction, with no distinct effect on the medium to coarse sand fraction.

SECTION VI - WELL HYDROGRAPH ANALYSIS

1. Data

1.1. Piezometer data from 21 groundwater wells were obtained so that groundwater piezometer hydrographs could be constructed for each well. These hydrographs are presented in Appendix VI as Plates VI.1 through VI.22. Ten of these wells are located within or directly adjacent to the Niobrara townsite.

2. Trend Analysis

2.1. Plates VI.1 through VI.21 show groundwater piezometer hydrographs for the wells located within or near the Niobrara townsite (Plate I.3). Of these wells, #1, and #2 are located less than 0.5 miles from the Niobrara River, #3, #4, #5, and #6 are within 0.25 miles of the Missouri River, and #8, #9, #10, and #11 are on the southern margin of both the Missouri River alluvial valley and the town of Niobrara.

2.2. The Niobrara Townsite #1 well is located approximately 0.5 miles east of the Niobrara River. The plot displays a continually increasing piezometric surface elevation at the site between 1961 and 1986. The well located downstream, Niobrara Townsite #2, shows an overall increase in piezometric surface elevation that was interrupted by a period of groundwater elevation stability between 1972 and 1980. The wells located on the Missouri River (#3, #4, #5 and #6) show a similar trend, that is, an overall increase in piezometric surface elevation with a period of stability from 1972 and 1980. Whereas the total increase for Well #1 was approximately 3 feet, the wells on the Missouri River came up on the order of 5 feet.

2.3. The Niobrara townsite wells #8, #9, #10, #11 and the USGS well also portray an increasing water table elevation with time (Plates VI.8 through VI.12). Each of these plots displays a distinct dip in water table elevation between 1974 and 1986. The average rise for these wells has been on the order of 3 to 5 feet.

2.4. The groundwater piezometer hydrographs for the Missouri River wells DH-83-01 through DH-83-03A are shown in Plates V.13 through V.16. The plots all show a continual decline in piezometric surface elevation of approximately 3 feet between 1983 and 1991. The wells are all located several miles upstream of the Niobrara River confluence, between RM 858 and RM 862.

2.5. The Niobrara River groundwater piezometer hydrographs are presented as Plates V.17 through Plates V.21. The wells are all located adjacent to the Niobrara River between RM 6 and RM 14. The plots show no distinct trends. There do, however, show distinct seasonal fluctuations in the height of the piezometric surface. Wells No. DH-83-07 and DH-83-08, are anomalous in that they show a generally decreasing trend in piezometric surface elevation that totals approximately 2 feet.

SECTION VII - SUMMARY OF RESULTS

1. Introduction

1.1. This study was conducted with the primary objective of compiling existing data related to the sedimentologic and geomorphologic characteristics of the Niobrara and Missouri Rivers in the vicinity of their confluence. No original data were collected during this study. The ultimate goal of the compilation is to provide a database that can be utilized to address concerns related to continued sediment deposition at the mouth of the Niobrara River. Potential consequences of delta development and growth at the confluence include loss of channel capacity, lateral channel destabilization resulting in increased bank erosion, increased overbank flooding, and increased water table elevations adjacent to the streams. Although this report provides an analysis of historic trends in the study reach, the analysis does not provide a forecast of future channel behavior. The historic trend analyses contained within this report constitute a database from which future trends could be predicted if such a study is warranted in the future.

1.2. The primary elements of the study include the evaluation of changes in gage height, channel geometry and sediment size distributions on the Niobrara River from the confluence with the Missouri River upstream approximately 14.5 miles, and on the main stem of the Missouri River from about 4.5 miles downstream to about 3.5 miles upstream of the confluence. Gage height trends within the study reach were evaluated by comparing stage/discharge relationships over a period of approximately 35 years at 2 Niobrara River stream gages and 3 Missouri River gages. The channel geometry analysis consisted of evaluating changes in the geometric characteristics of surveyed cross sections at a total of 33 ranges in the study area, 11 of which are located on the Missouri River and 22 on the Niobrara River. Hydraulic elements and parameters evaluated include channel width, mean channel depth, cross sectional area, mean bed elevation, and thalweg elevation. Bed sediment gradation data were utilized to evaluate sediment size distributions within the study reach.

1.3. A primary objective of this study is to document the effect of Lewis and Clark Lake and Fort Randall Dam releases on the geomorphologic characteristics of the study reach. Fort Randall Dam, located on the Missouri River 35 miles upstream of the Niobrara River confluence, was closed in 1952. Gavins Point Dam, located on the Missouri River 35 miles downstream of the Niobrara River confluence was closed in 1955. Since closure of the dams, large seasonal fluctuations in the Missouri River flows have been eliminated, reducing the ability of the Missouri River to transport sediment delivered by the Niobrara River downstream of the confluence. A large delta has formed at the confluence as a result of the reduced transport capacity of the Missouri River after dam closure.

2. Summary of Results

2.1. The primary results of this data compilation and trend evaluation are included as plates and tables within Appendices I through VI. Location maps and data resource availability tables are contained within Appendix I. Appendix II contains plots of rating curve trends. These plots contain stage/discharge relationships through time for 5 stream gages in the study reach. The channel geometry

analysis is based upon plotted channel cross sections as well as hydraulic element and hydraulic parameter trends. The plotted cross sections are contained within Appendix III. Most of the ranges evaluated are represented by a series of plots, each of which contain 3 to 4 cross sections. The cross section from the original survey is repeated on each plot to maintain a general reference baseline for ease of comparison. Hydraulic element trends are presented in Appendix IV. The hydraulic element analysis consisted of evaluating changes in channel width, mean channel depth, and cross sectional area with elevation for each cross sections. Hydraulic parameter trends are contained within Appendix IV. The hydraulic parameters were evaluated along the length of the study reach in reference to specific reference planes determined for each cross section. Bed material gradation trends are presented in Appendix V, and groundwater well hydrographs are presented in Appendix VI.

2.2. The objective of the gage trend analysis is to compare sequential rating curves to determine the variation in stage for specific discharges through time. The gage trends developed in this study are presented in Plates II.1 through II.5 in Appendix II. The general trend depicted by the Niobrara River stage/discharge relationships is an increase in stage over the period of record characterized by rapid increases followed by short periods of relative stability. The increasing stage on the Niobrara River is likely the result of continued growth of the Niobrara River delta during periods of significant sediment delivery from the Niobrara River coupled with relatively low flows on the Missouri River. The most rapid increase in stage elevation at these two gages during the period for which rating curves are available occurred between 1974 and 1985.

2.3. The two Missouri River gages that are located within a few miles of the Niobrara River confluence are characterized by a trend of increasing stage elevation. A marked increase in stage elevation occurred at these two gage sites between 1977 and 1986, similar to the Niobrara River gages. In addition, rapid rise in stage elevation occurred on the Missouri River at Niobrara between 1957 and 1960. The Missouri River at Greenwood gage, located approximately 20 miles upstream of the Niobrara River confluence, shows no consistent change in stage with time. The gage trend analysis indicates that the study reach has been characterized by a general increase in stage through time for a given discharge. This increase has been most pronounced at the confluence of the Niobrara River and Missouri Rivers, indicating that the rise in stage can be attributed to deposition of Niobrara River sediment at the confluence.

2.4. Plates IV.1 through IV.96 contain hydraulic element plots for each of the ranges considered in this study. The plots depict general channel infilling along the study reach. Channel area has been lost at each of the ranges due to sediment deposition in the channel bed. Bank erosion has occurred locally. In general, delta development and growth has been characterized by general aggradation and reduction of mean channel depth and cross sectional area with minor associated bank erosion and channel widening. Channel infilling on the Niobrara River extends from the mouth upstream to at least RM 9.

2.5. Hydraulic parameter plots contained as Plates IV.97 through IV.106 show spatial and temporal trends in evaluated parameters along the study reach.

2.6. On the Niobrara River, the thalweg profile shows a slight increase in thalweg elevation

between 1956 and 1983 at RM 12 near the Verdel gage which corroborates the gage trend at that location (Plate IV.97). Downstream of RM 7.0, the profiles show a significant increase in thalweg elevation through time from RM 7.0 downstream to the mouth. The average bed elevation profile displays much less variability than the thalweg profile (Plate IV.98). From 1956 to 1983, there has been a net increase in average bed elevation of approximately 3 feet between RM 5.0 and RM 7.0, and an increase of approximately 5 feet at the mouth of the Niobrara River. Channel topwidth has not changed in any consistent manner through time (Plate IV.99). The data indicate that channel topwidth increases gradually downstream through the study reach to approximately RM 1.0, at which point the channel abruptly narrows. Similar to channel width, channel depth increases in the downstream direction for a given year (Plate IV.100). Through time, there has been a consistent trend of depth reduction throughout the study reach. This depth reduction ranges from approximately 0.3 feet upstream of RM 9 between 1956 and 1975 to over 4 feet at the mouth of the river between 1956 and 1983. The trend in cross sectional area is very similar to that of channel depth (Plate VI.101). The most dramatic reduction in cross sectional area for the available data has occurred downstream of RM 9.0.

2.7. On the Missouri River, the thalweg profiles are extremely erratic in nature (Plate IV.102). There is no apparent trend of rising or lowering thalweg elevation through time on the Missouri River study reach. In contrast, the average bed elevation profiles show a general increase between 1954 and 1984 (Plate IV.103). Upstream of the Niobrara River confluence, the rise has averaged approximately 2 feet between 1954 and 1985. For the same time period downstream of the confluence, the rise in average bed elevation has ranged between 2 and 6 feet. This probably reflects downstream reworking of Niobrara River sediment by the Missouri River and may reflect some additional growth of the Niobrara River delta. Channel topwidths on the Missouri River study reach are highly variably spatially, but have remained relatively constant through time (Plate IV.104). There has been an overall reduction in channel depth of approximately 3 to 5 feet downstream of the confluence and 2 feet upstream of the confluence between 1954 and 1984. Channel area trends depict a similar reduction in cross sectional area. Channel cross section plots show that some widening has occurred at Missouri River Ranges 883.9 and 884.4 (Plates 111.49 to 111.54).

2.8. Bed sediment gradation plots indicate that the dominant sediment size through the study reach for both the Missouri and Niobrara Rivers is sand. The fine fraction of Missouri River bed sediment is slightly coarsened by Niobrara River input, however the coarsest fraction is relatively unaffected (Plates V.1 through V.10).

2.9. Groundwater piezometer hydrographs from the Niobrara townsite depict a general increase in piezometric surface elevation for the period of record which extends from 1961 to 1986. Several of the hydrographs display a period of piezometric surface stability between 1972 and 1980. The increase in piezometric surface elevations at these well sites has been on the order of 3 to 5 feet. The groundwater wells located adjacent to the Missouri River upstream of the Niobrara River confluence display a continual decline in piezometric surface elevation of approximately 3 feet between 1983 and 1991. The wells located

on the Niobrara River between RM 6 and RM 14 show distinct seasonal variation in the elevation at the piezometric surface. Two wells show a general decrease in piezometric surface elevation of about 2 feet between 1983 and 1991. This decline clearly overprints the seasonal variation of ground water table elevations.

APPENDIX I

AVAILABLE DATA AND LOCATION MAPS

Table I.1. Existing Stage Discharge Curves.

	Niobrara River		Missouri River		
Year	Near Verdel	At Hwy #12	At Greenwood	Near Verdel	At Niobrara
1938	X				
1939	X				
1940					

1956					X
1957					X
1958	X				X
1959	X				X
1960	X		X		X
1961	X		X		X
1962	X		X		X
1963	X				X
1964	X				X
1965	X		X		X
1966	X	X	X		X
1967	X	X	X		X
1968	X	X		X	X
1969	X	X		X	X
1970	X	X		X	X
1971	X	X	X	X	X
1972	X	X	X	X	X
1973	X	X	X	X	
1974	X	X	X	X	X
1975		X	X	X	X
1976		X			X
1977		X		X	X
1978		X		X	X
1979			X	X	X
1980		X	X	X	X
1981			X		
1982					
1983			X		
1984			X		
1985			X		
1986		X		X	X
1987		X	X	X	X
1988	X	X		X	X
1989		X		X	X
1990	X	X	X	X	X

Table I.2. Discharge Data, Niobrara and Missouri Rivers.

Year	Niobrara River Near Verdel		Missouri River Fort Randall	
	Total Annual Inflow (Ac-Ft)	Annual Peak Discharge (cfs)	Annual Peak Discharge (cfs)	Total Annual Inflow (Ac-Ft)
1948	---	---	103,000	---
1949	---	---	182,000	---
1950	---	---	249,000	23,181,210
1951	---	---	134,000	21,852,484
1952	---	---	447,000	28,871,092
1953	---	---	109,000	19,435,448
1954	---	---	34,300	15,138,537
1955	---	---	41,900	15,174,815
1956	---	---	53,400	---
1957	---	---	44,700	12,198,023
1958	---	---	42,500	12,983,016
1959	1,058,171	7,670	47,400	13,220,621
1960	1,389,952	39,000	87,700	10,620,267
1961	1,082,441	6,290	45,500	12,788,621
1962	1,781,454	25,600	74,400	8,097,120
1963	1,335,768	10,100	52,700	13,190,135
1964	1,174,686	28,700	43,500	13,642,604
1965	1,061,694	4,880	46,600	13,452,032
1966	1,156,244	16,000	40,500	16,837,518
1967	1,079,234	9,460	46,600	16,780,156
1968	1,119,278	6,740	42,700	19,299,500
1969	1,014,115	9,000	52,000	20,499,758
1970	1,039,350	5,040	48,000	21,633,906
1971	1,037,633	6,600	47,500	24,355,424
1972	1,086,852	6,320	50,500	25,768,846
1973	1,219,945	7,000	48,100	19,199,792
1974	1,116,892	3,710	42,100	17,971,626
1975	983,992	3,600	60,600	23,327,392
1976	921,024	3,800	60,600	25,758,134
1977	1,115,880	6,400	41,700	18,502,998
1978	1,189,150	11,200	51,700	19,633,378
1979	1,045,009	4,150	53,200	22,616,318
1980	1,038,616	4,890	41,700	19,128,584
1981	921,219	4,090	39,600	18,424,652
1982	1,136,388	4,950	33,700	15,445,876
1983	1,471,211	7,400	39,500	17,318,470
1984	1,548,051	7,790	44,600	17,488,652
1985	1,150,274	4,570	44,000	18,507,956
1986	---	5,910	40,100	16,428,884
1987	1,405,598	7,040	45,100	---
1988	1,379,987	6,730	---	---
1989	1,017,951	---	---	---

Table I.3. Range Cross Section Surveys and Hydraulic Elements Tables.

Missouri River Range	1960 River Mile	1954	1955	1956	1960	1961	1965	1970	1975	1979	1983	1985
888.9	847.3		X		X		X	X	X	X		X
886.8	845.2	X			X		X	X	X	X		X
885.6	844.1		X		X		X	X	X	X		X
885.1	843.6	X			X		X	X	X	X		X
884.4	842.9	X			X		X	X	X	X		X
883.9	842.4	X			X		X	X	X	X		X
883.3	841.9	X			X		X	X	X	X		X
882.6	841.2	X			X		X	X	X	X		X
882.0	840.6	X			X		X	X	X	X		X
881.4	840	X			X		X	X	X	X		X
Niobrara River Range												
0.0				X	X		X	X	X			
0.1						X	X	X	X			
0.5				X	X		X	X	X		X	
0.8				X	X		X	X	X		X	
1.1				X	X		X	X	X		X	
1.4				X	X		X	X	X		X	
1.9						X	X	X	X		X	
2.4				X	X		X	X	X		X	
3.0						X	X	X	X		X	
3.6				X	X		X	X	X		X	
4.0						X	X	X	X		X	
4.4				X	X		X	X	X		X	
5.2				X	X		X	X	X		X	
6.0											X	
6.9				X	X		X	X	X		X	
8.0											X	
9.0				X	X		X	X	X		X	
10.5											X	
11.6											X	
13.0				X	X		X	X	X		X	
13.8											X	
14.5											X	

Table I.4. Reference Plane Elevations.

Niobrara River		Missouri River		
Range	Reference Plane Elevation (ft)	Range	1960 River Mile	Reference Plane Elevation (ft)
0.0	1,221			
0.1	1,221.6	881.4	840.0	1,216.6
0.5	1,224.2	882.0	840.6	1,217.1
0.8	1,226.1	882.6	841.2	1,217.5
1.1	1,227.9	883.3	841.9	1,218.0
1.4	1,229.8	883.9	842.4	1,218.4
1.9	1,233.0	884.4	842.9	1,218.7
2.4	1,235.9	885.1	843.6	1,219.2
3.0	1,239.4	885.6	844.1	1,219.6
3.6	1,242.9	886.8	845.2	1,220.4
4.0	1,245.2	888.9	847.3	1,221.9
4.4	1,247.5			
5.2	1,252.1			
6.0	1,256.8			
6.9	1,262.0			
8.0	1,269.4			
9.0	1,276.1			
10.5	1,286.2			
11.6	1,293.6			
13.0	1,303.0			
13.8	1,312.1			
14.5	1,320.0			

Table I.5. Bed material sediment data.

Missouri River 1960 River Mile	1957	1967	1975	1980
839.3			X	
840.0			X	
840.6	X		X	
841.2			X	
841.9	X		X	
842.4			X	
842.9	X		X	
843.6			X	X
844.1	X	X	X	X
845.2		X	X	X
847.3	X	X	X	X

Niobrara River River Mile	1957	1963	1970	1975	1980
0.0	X	X	X	X	X
0.5	X	X	X	X	X
0.8	X	X	X	X	X
1.1	X		X	X	X
1.4	X	X	X	X	X
1.9		X	X	X	X
2.4	X	X	X	X	X
3.0		X	X	X	
3.6	X	X	X	X	X
4.0		X	X	X	X
4.4	X	X	X	X	X
5.2	X	X	X	X	X
6.3		X			
6.9	X		X	X	X
9.0	X		X	X	X
13.0	X		X	X	X

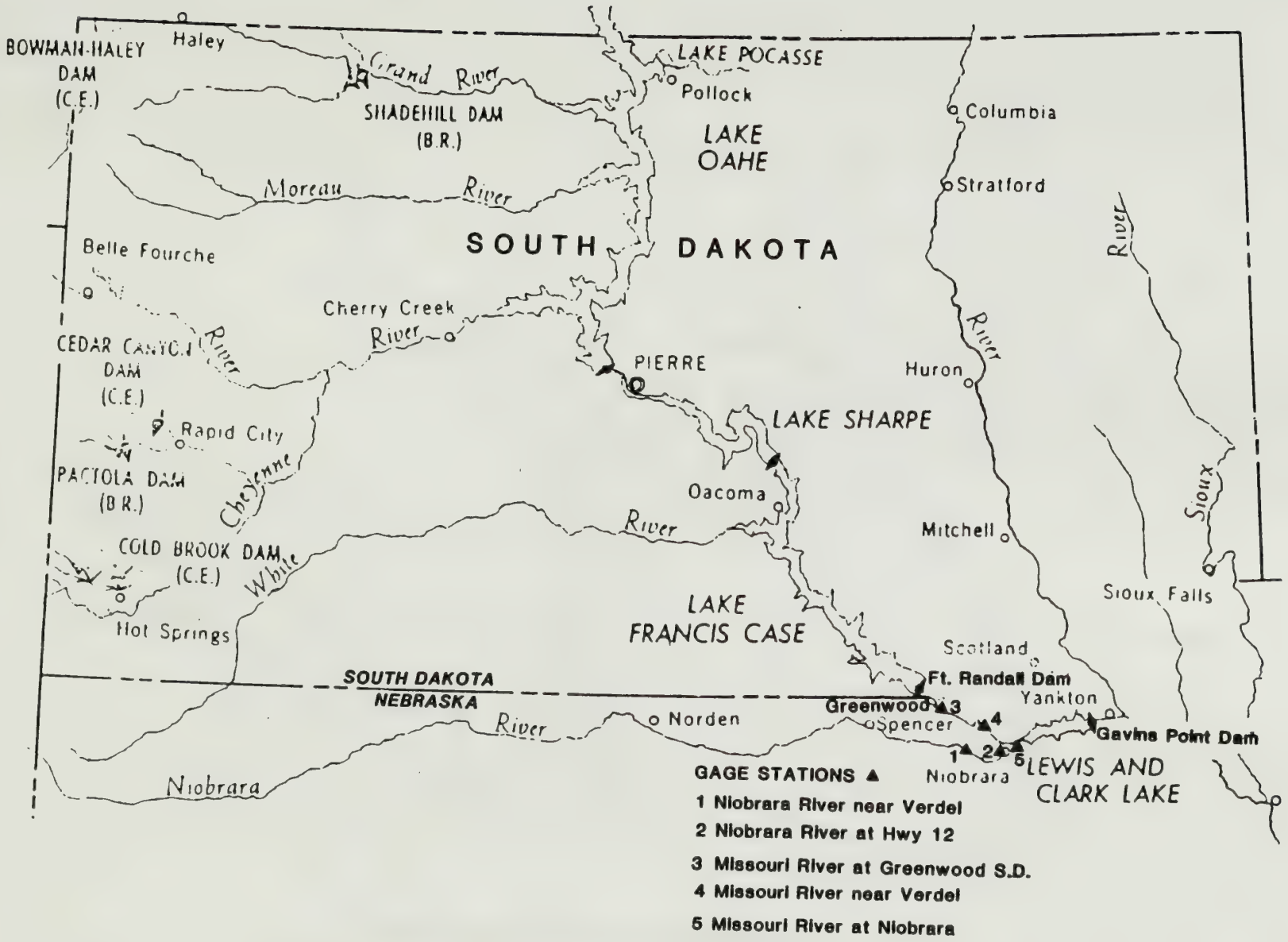


Plate I.1

Plate I.1: STUDY AREA & GAGE STATION LOCATIONS

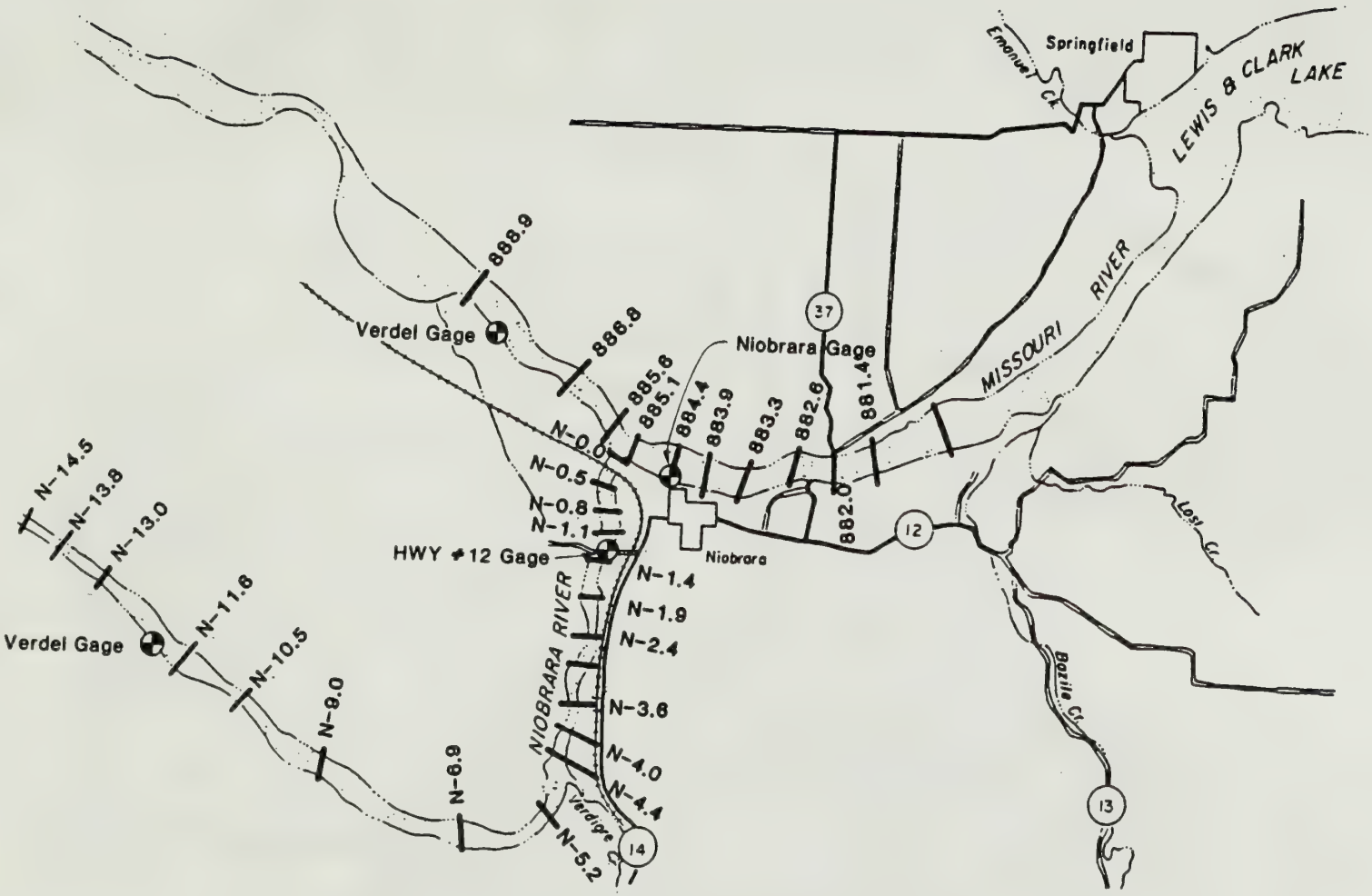


Plate I.2: RANGE LOCATION MAP

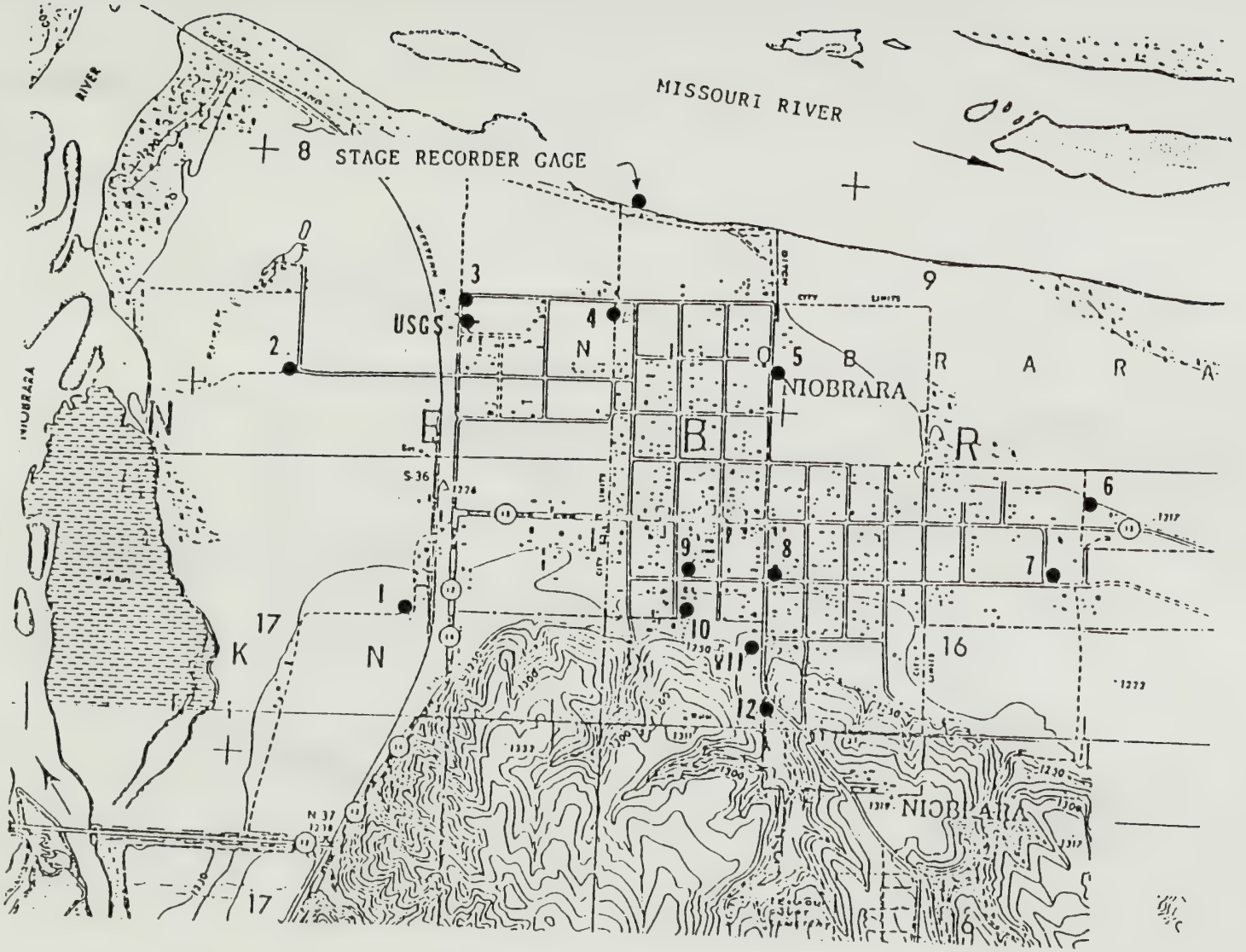


Plate I.3

Plate I.3: GROUNDWATER PIEZOMETER WELL LOCATIONS, WELLS NIOBRARA TOWNSITE 01 to 11, AND USGS #32-68-8dd

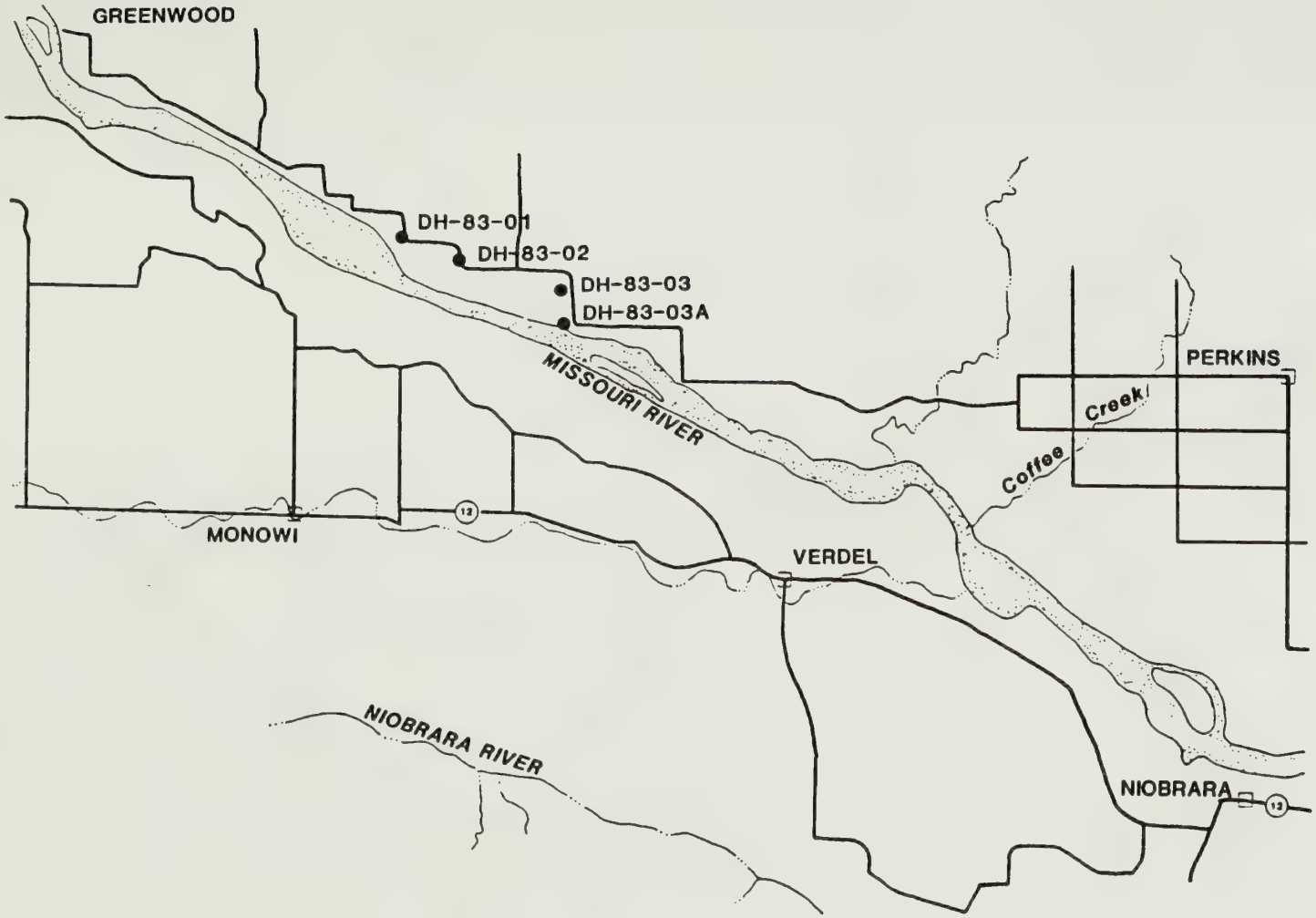


Plate I.4

Plate I.4: GROUNDWATER PIEZOMETER WELL LOCATIONS, WELLS DH-83-4 to DH-83-8

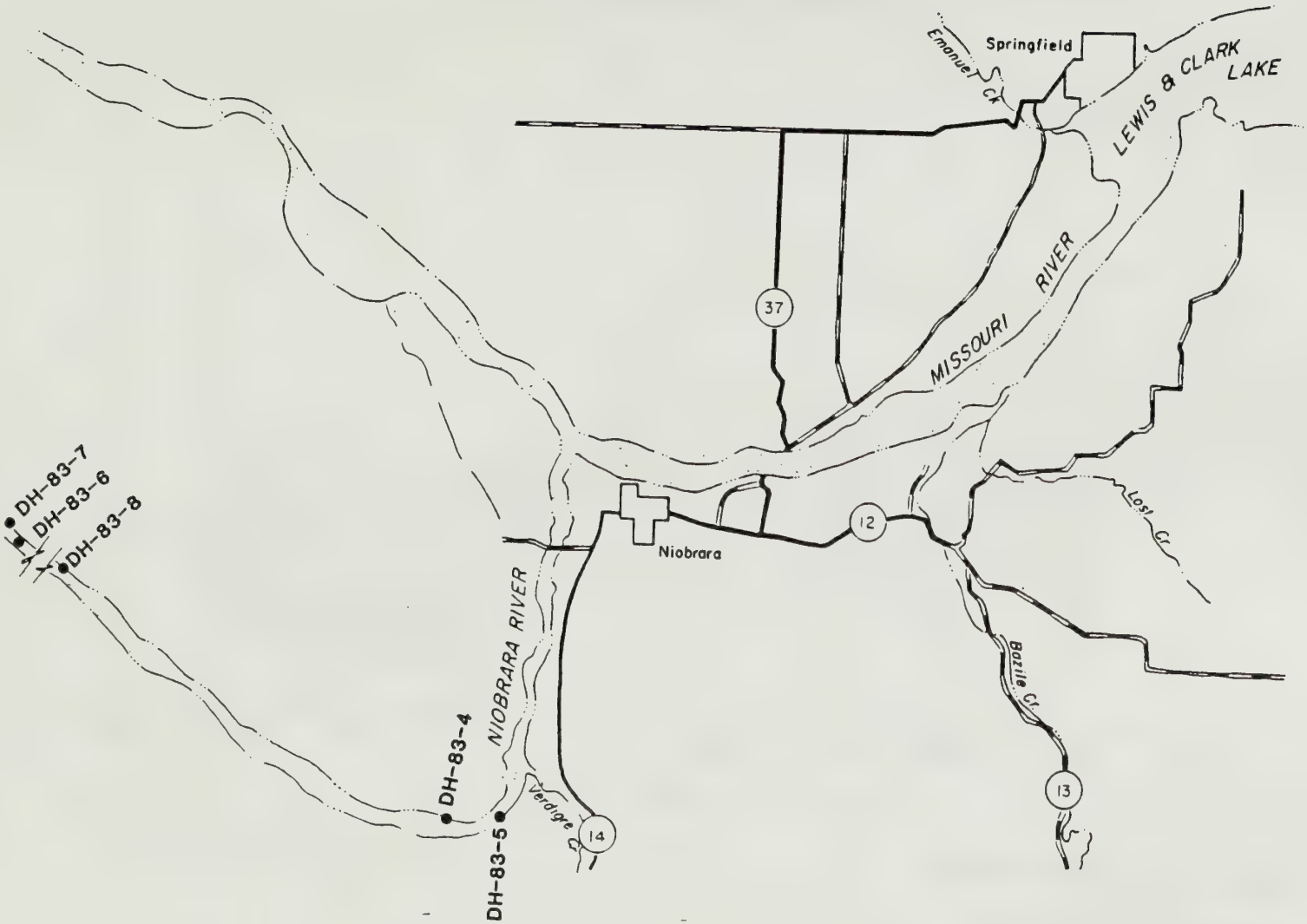
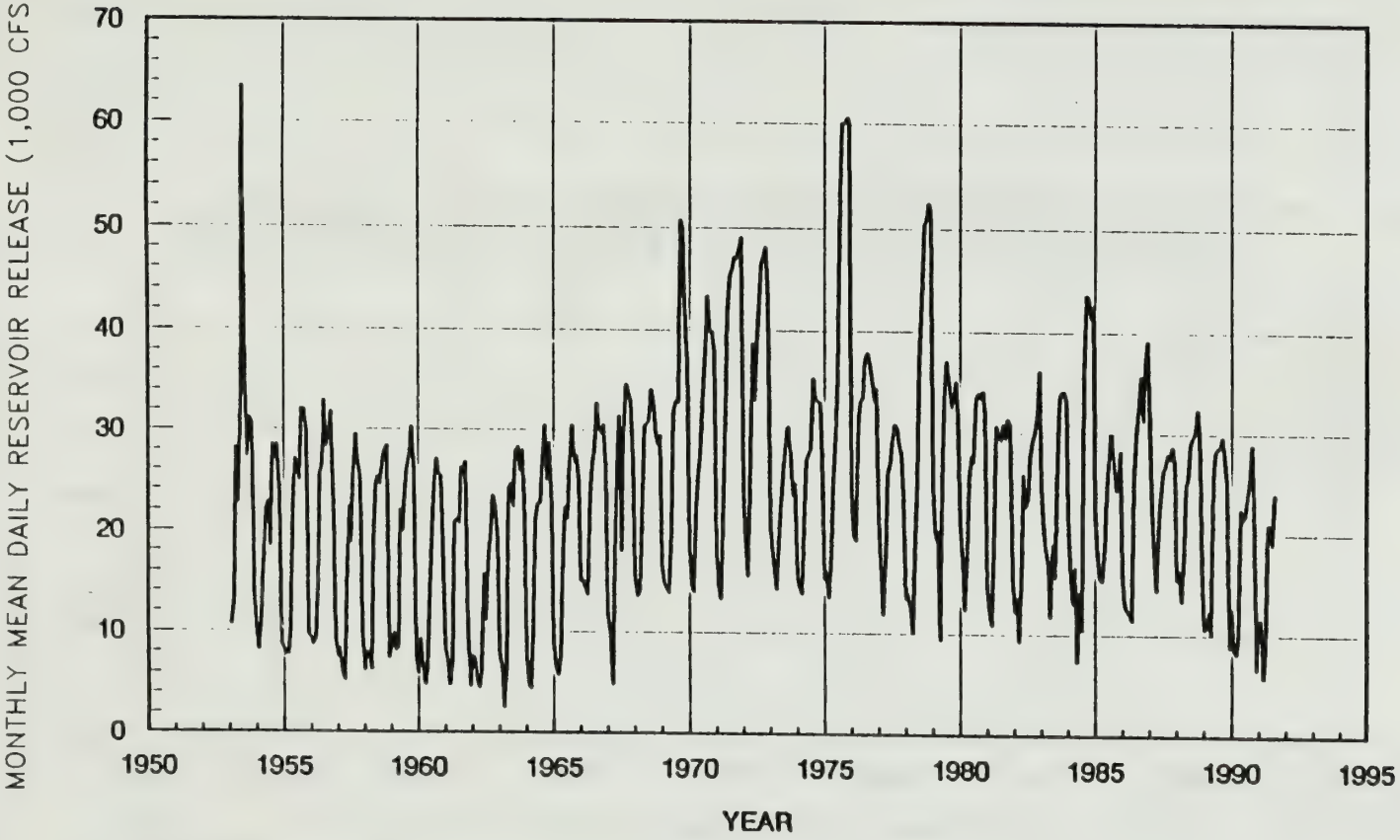


Plate I.5: GROUNDWATER PIEZOMETER WELL LOCATIONS, WELLS DH-83-01 to DH-83-03A

MONTHLY RESERVOIR RELEASE
FORT RANDALL DAM



Fort Randall Dam closed in July 1952

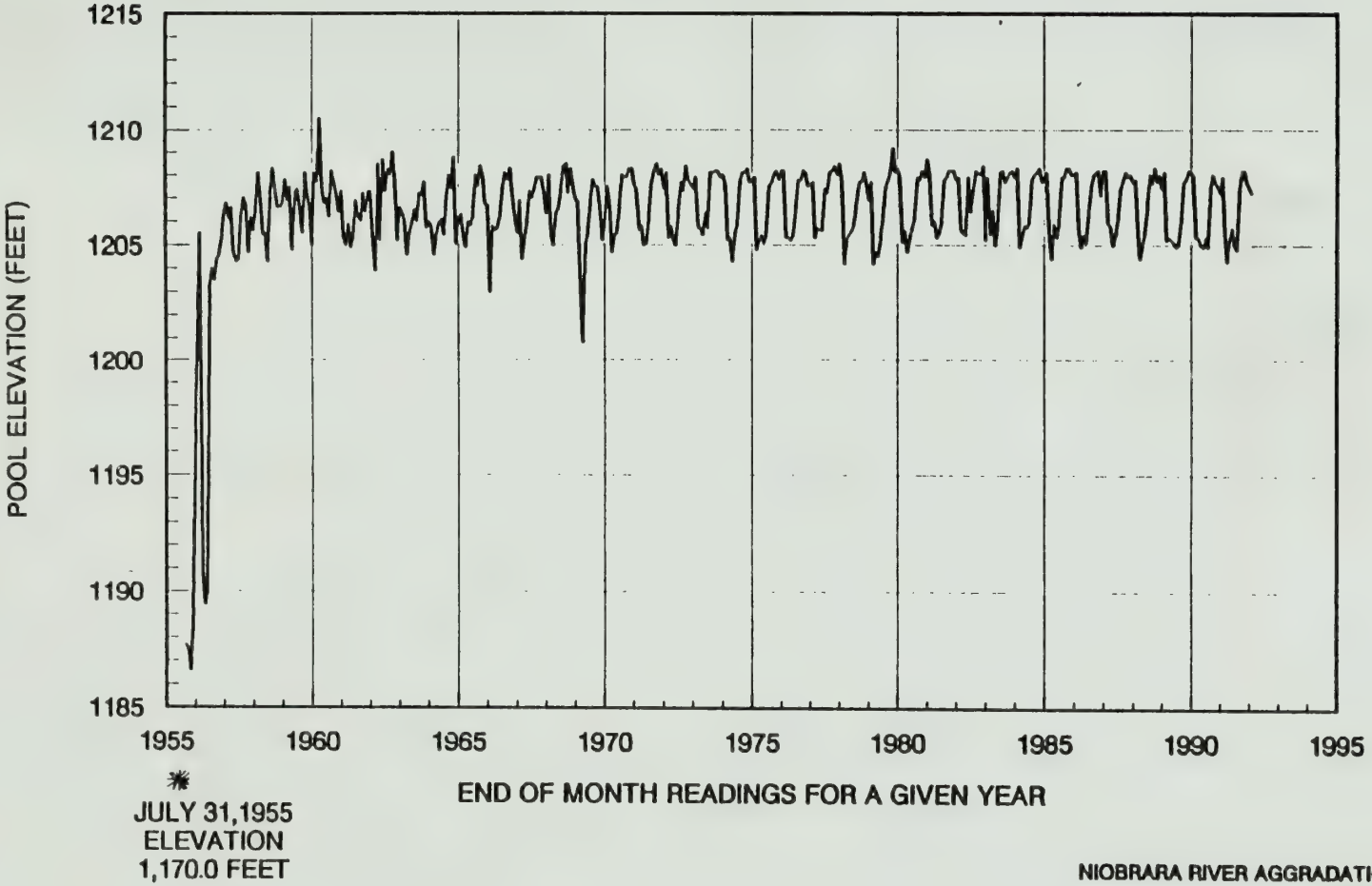
NIOBRARA RIVER AGGRADATION STUDY

MONTHLY
RESERVOIR RELEASE

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
APRIL 1992

Plate 1.6

END OF MONTH POOL ELEVATIONS
LEWIS AND CLARK LAKE



NIOBRARA RIVER AGGRADATION STUDY

END OF MONTH
POOL ELEVATIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
MAY 1992

Plate I.7

APPENDIX II

RATING CURVE TREND PLOTS

GAGE ON NIOBRARA RIVER AT HIGHWAY #12
(RIVERMILE 1.3)

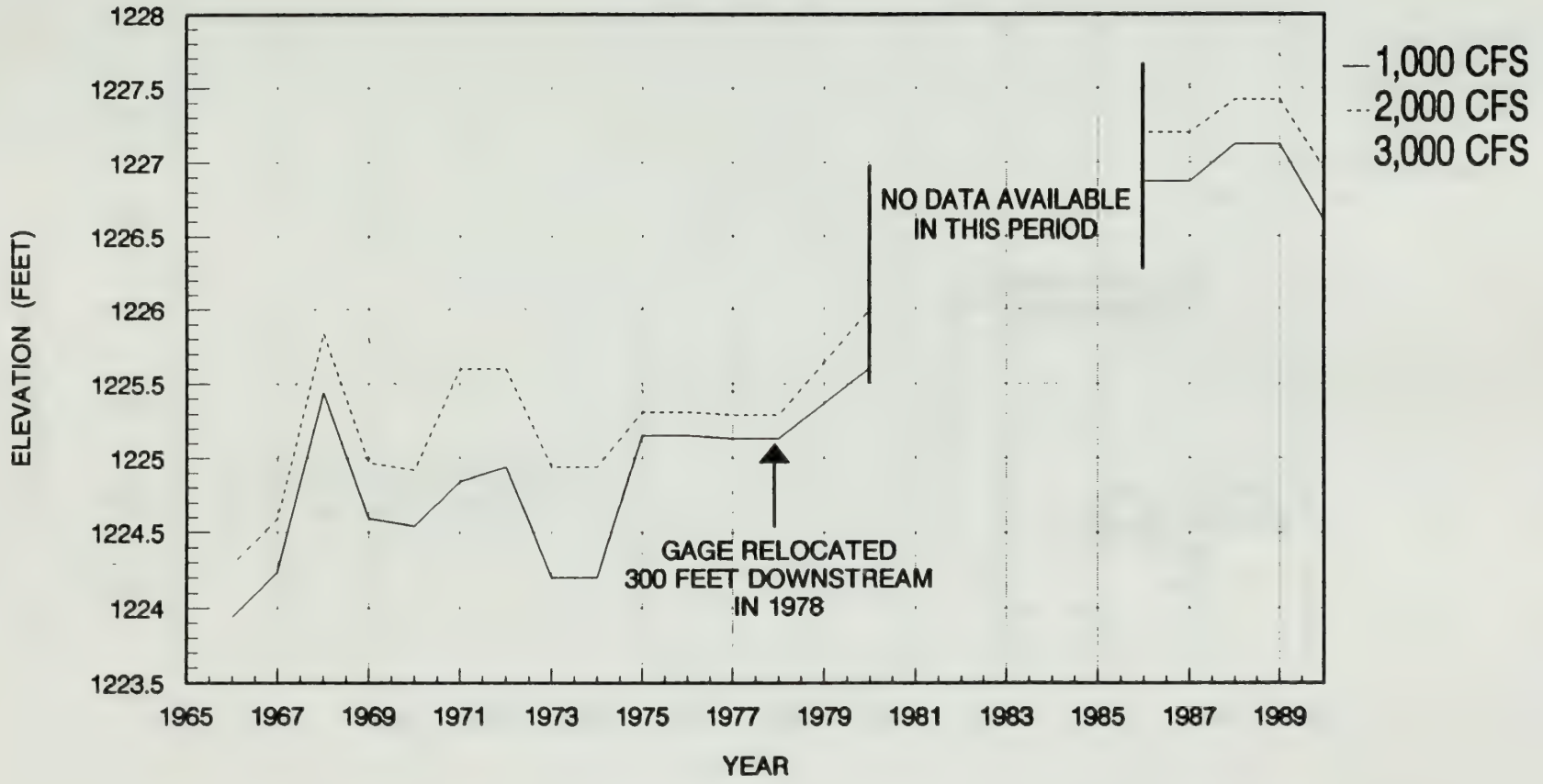


Plate II.1

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GAGING STATION TREND ANALYSIS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
MAY 1992

GAGE ON NIOBRARA RIVER NEAR VERDEL NEBRASKA
(RIVERMILE 12.0)

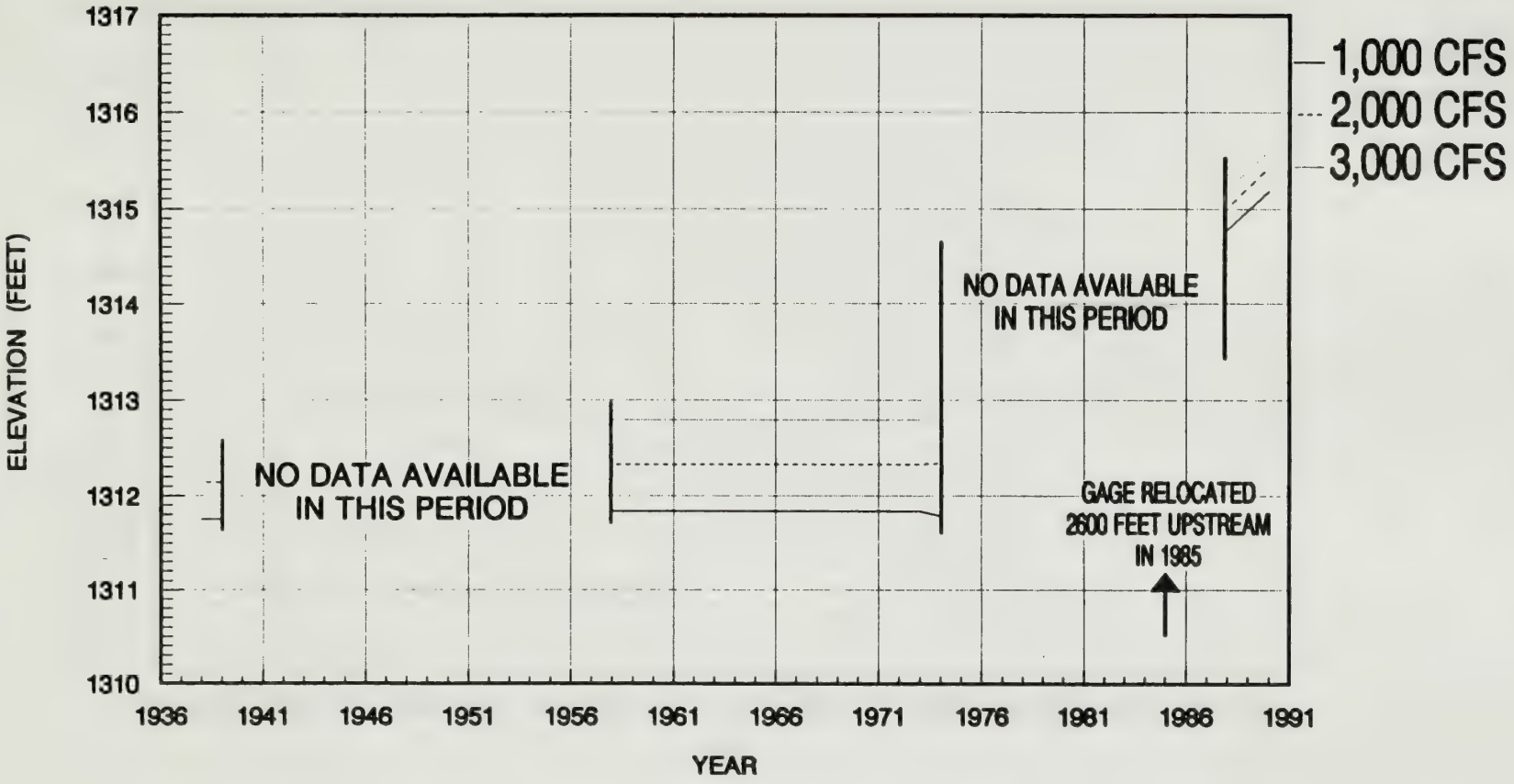


Plate II.2

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GAGING STATION TREND ANALYSIS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
MAY 1992

GAGE ON MISSOURI RIVER AT NIOBRARA, NEBRASKA
(1960 RIVERMILE 842.9)

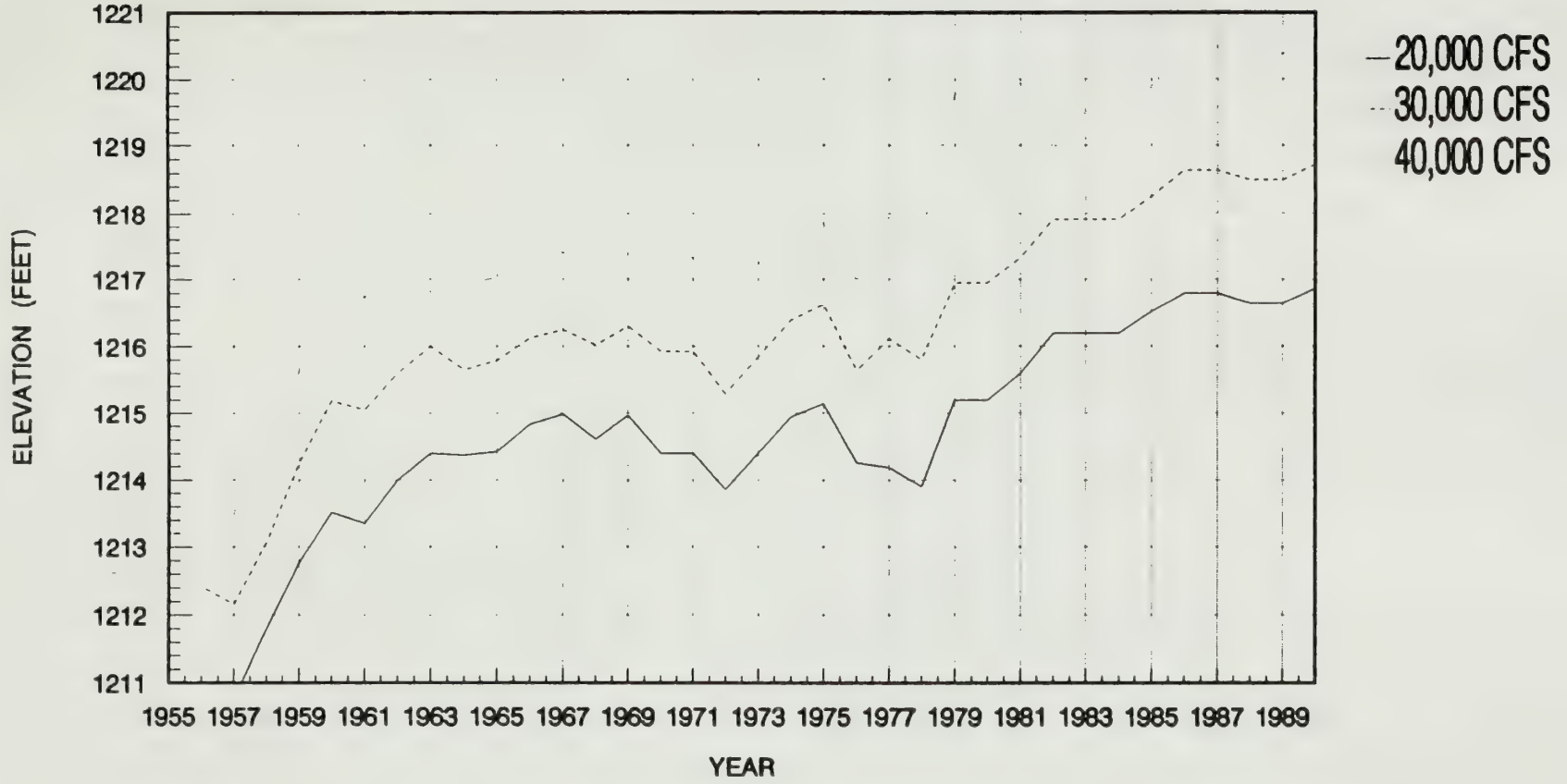


Plate II.3

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GAGING STATION TREND ANALYSIS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
MAY 1992

GAGE ON MISSOURI RIVER NEAR VERDEL NEBRASKA
(1960 RIVERMILE 846.5)

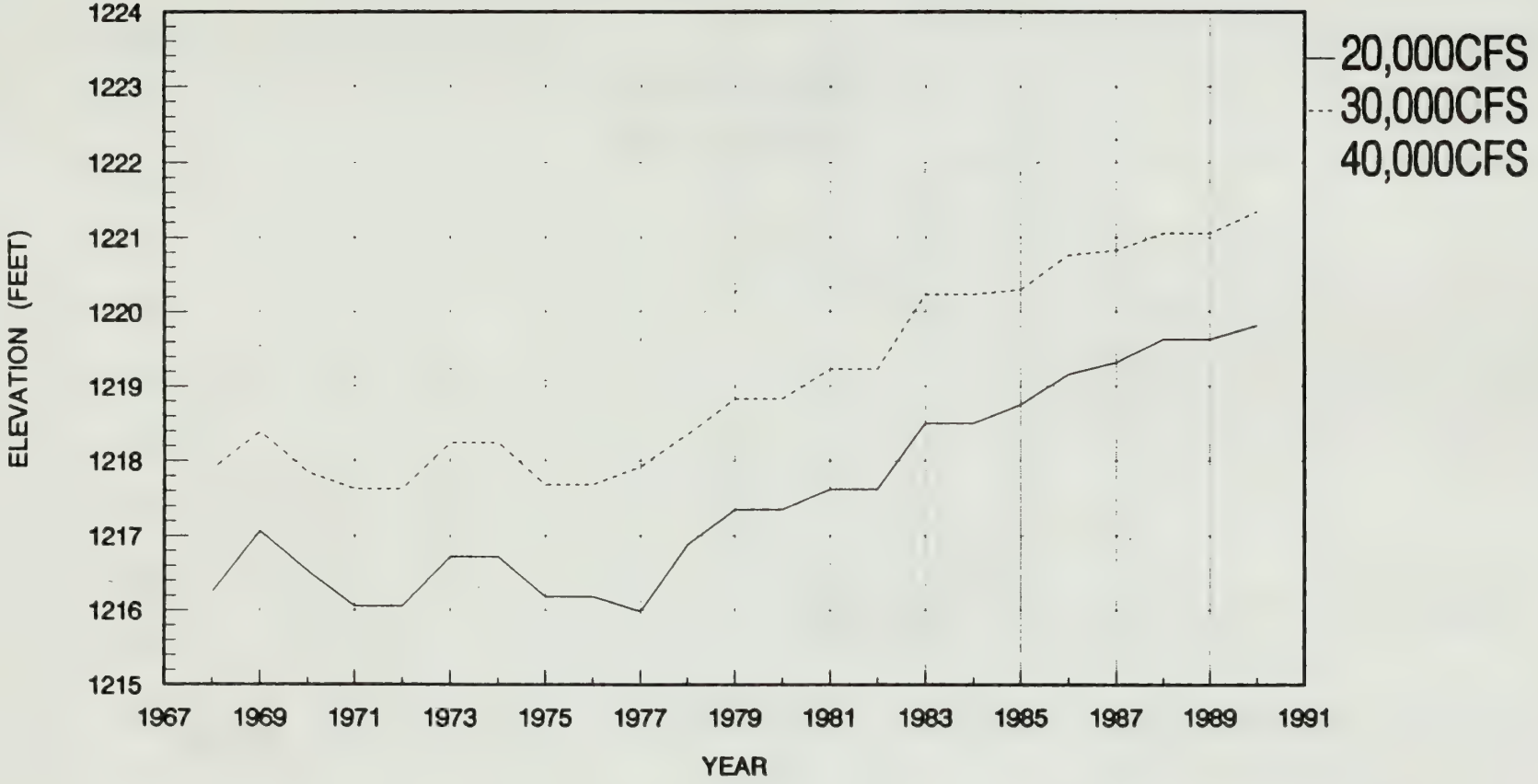


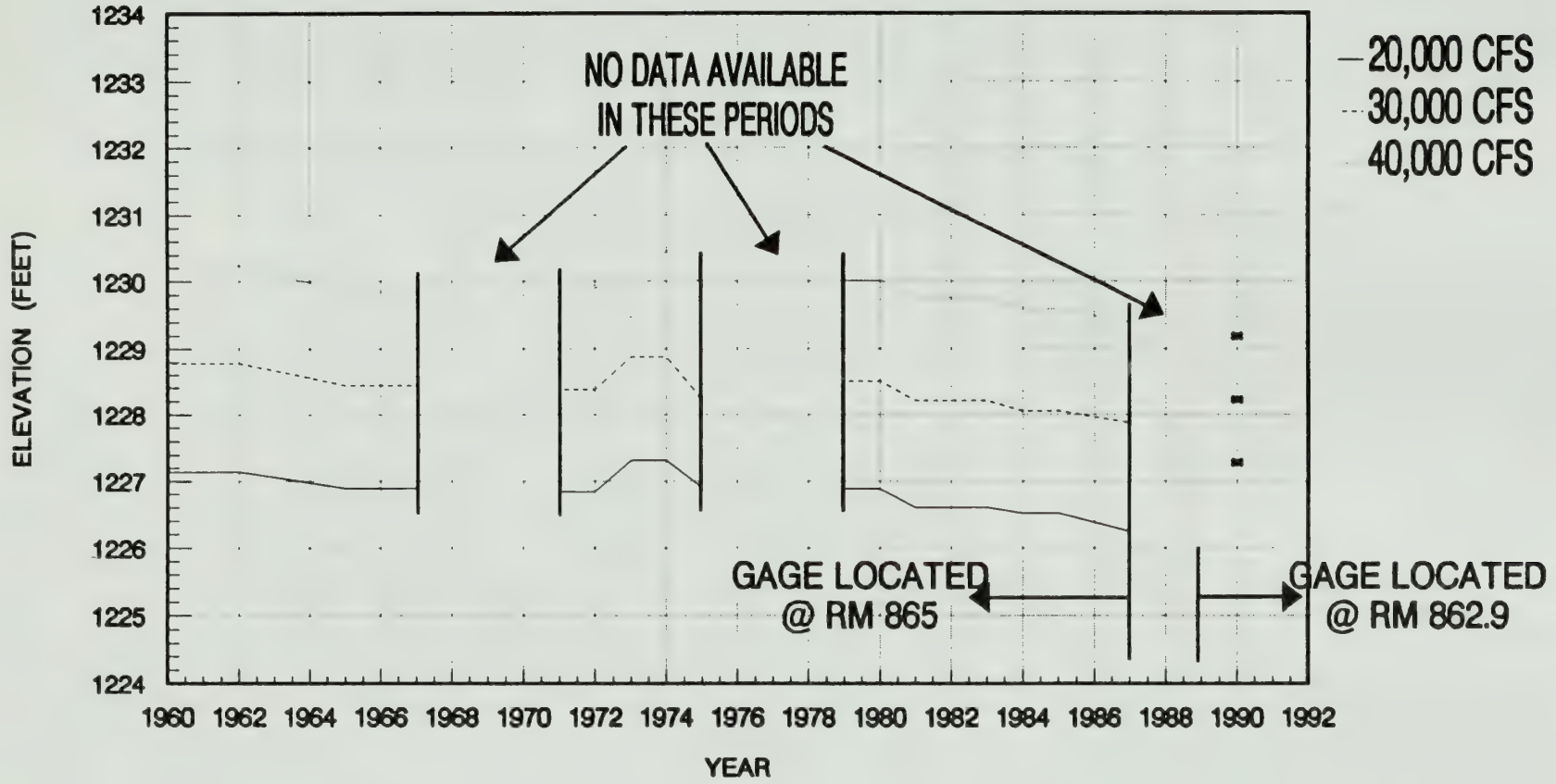
Plate II.4

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
GAGING STATION TREND ANALYSIS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
MAY 1992

GAGE ON MISSOURI RIVER AT GREENWOOD, SOUTH DAKOTA



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GAGING STATION TREND ANALYSIS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
MAY 1992

Plate II.5

APPENDIX III

CHANNEL CROSS SECTIONS

CROSS SECTION PLOT FOR RANGE N 0.0

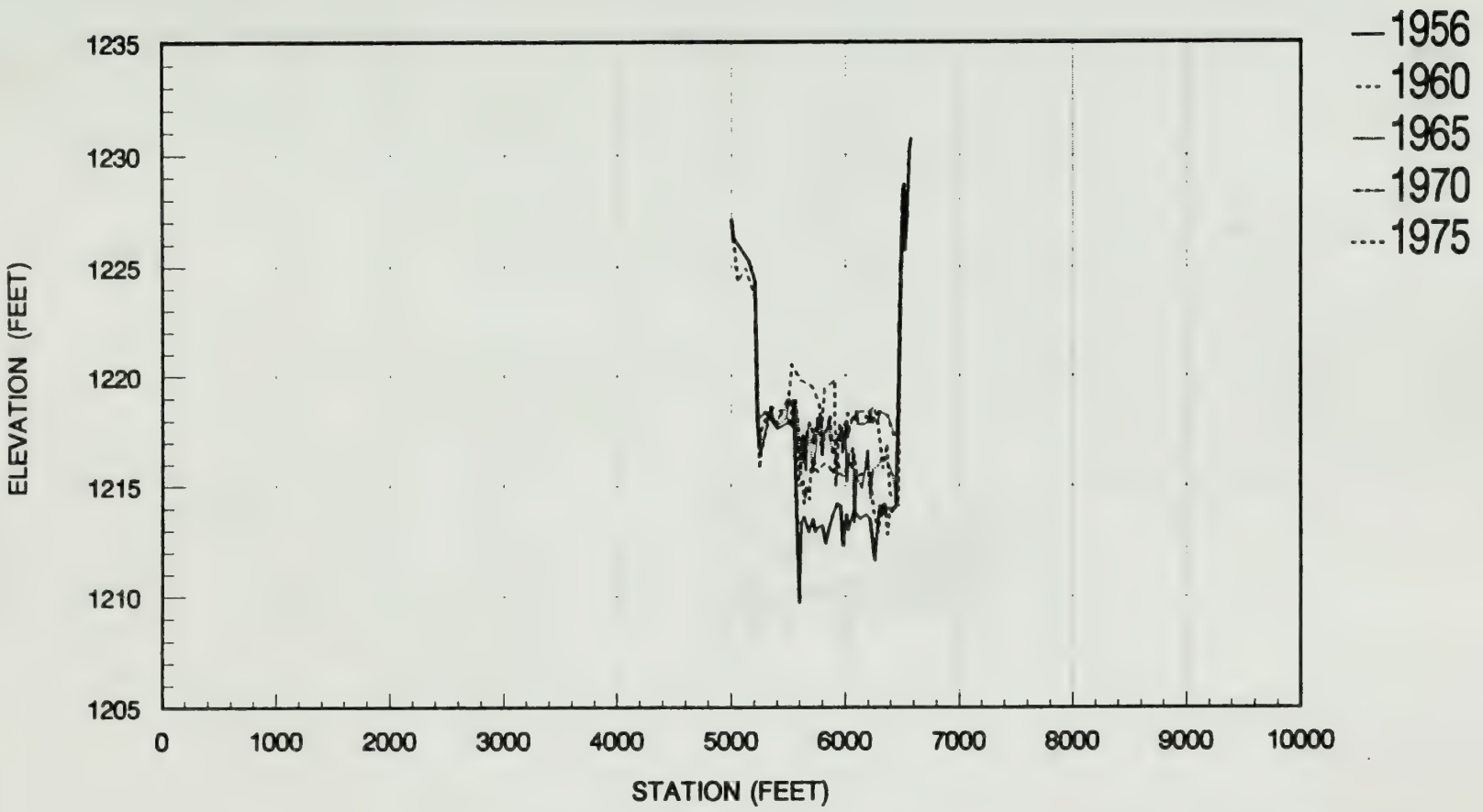


Plate III.1

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 0.1

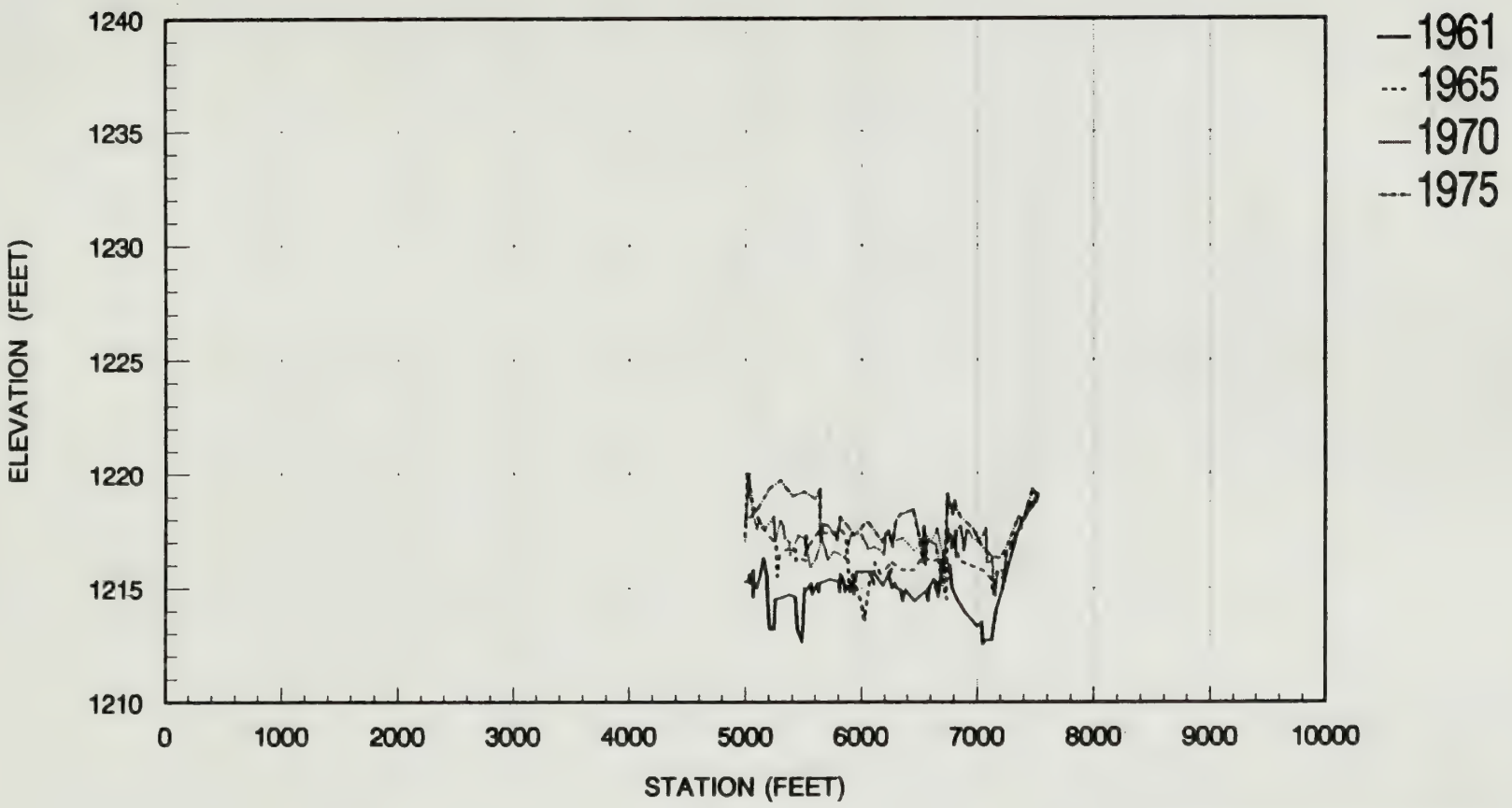


Plate III.2

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 0.5

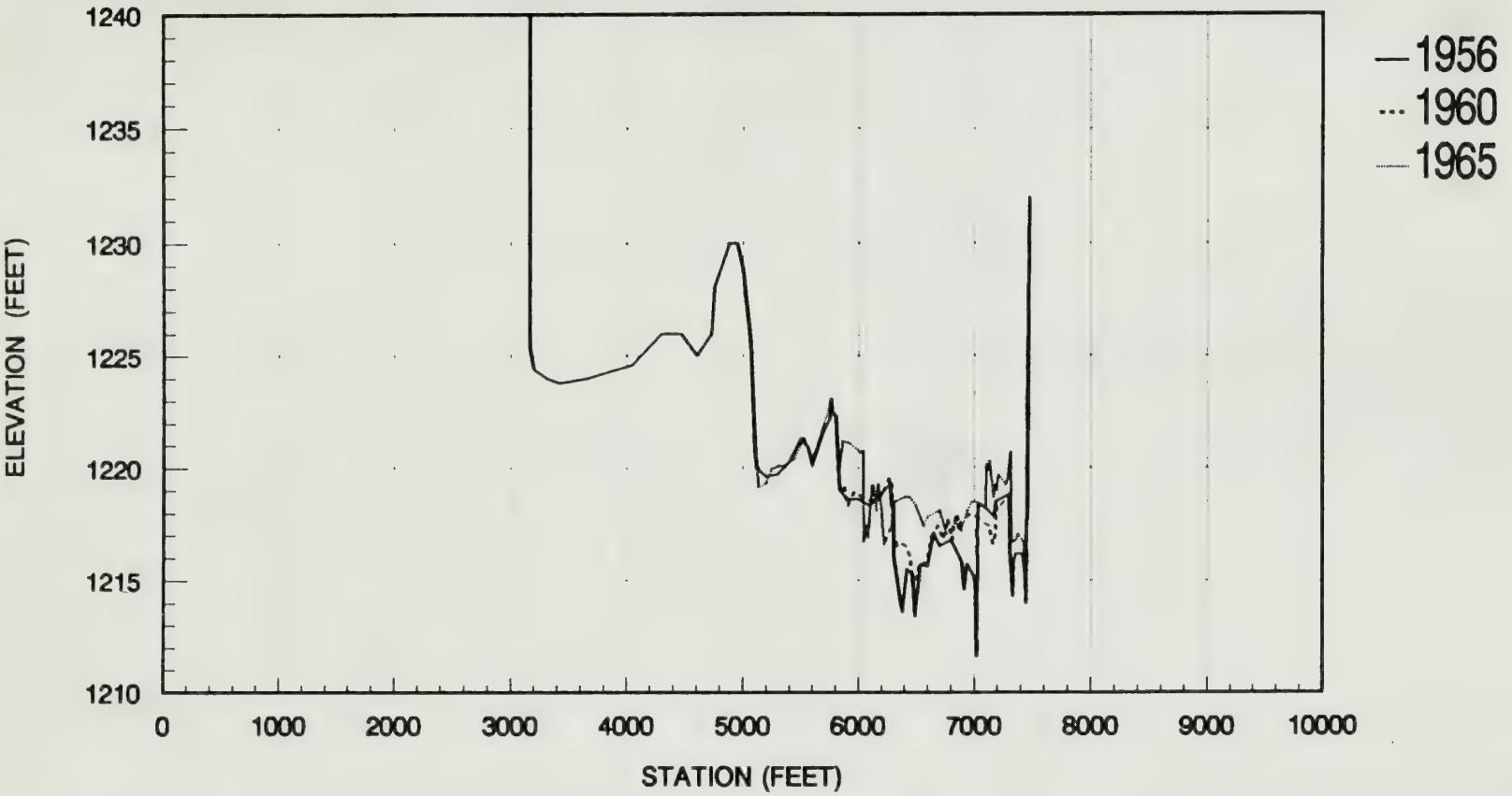


Plate III.3

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 0.5

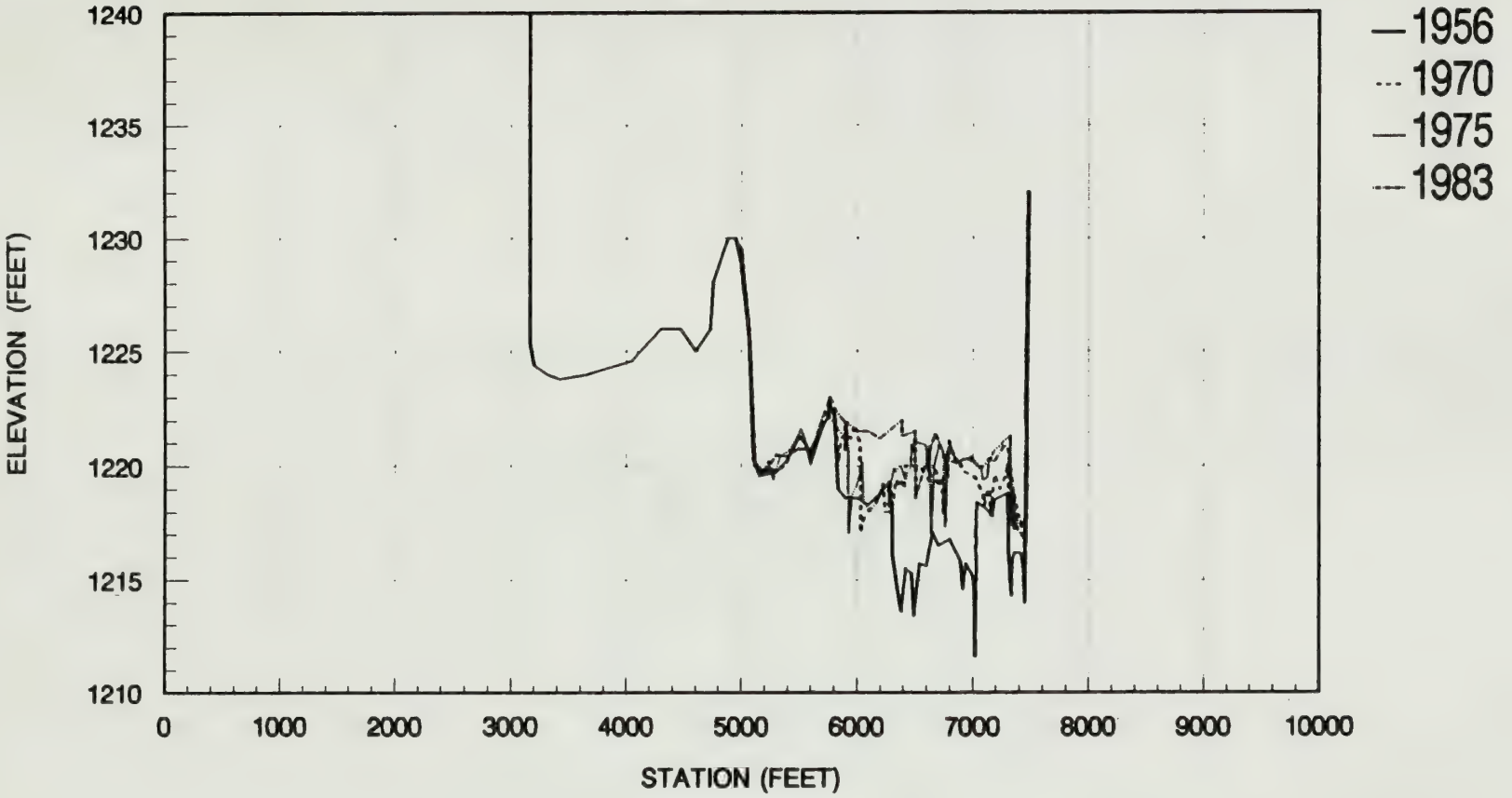


Plate III.4

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 0.8

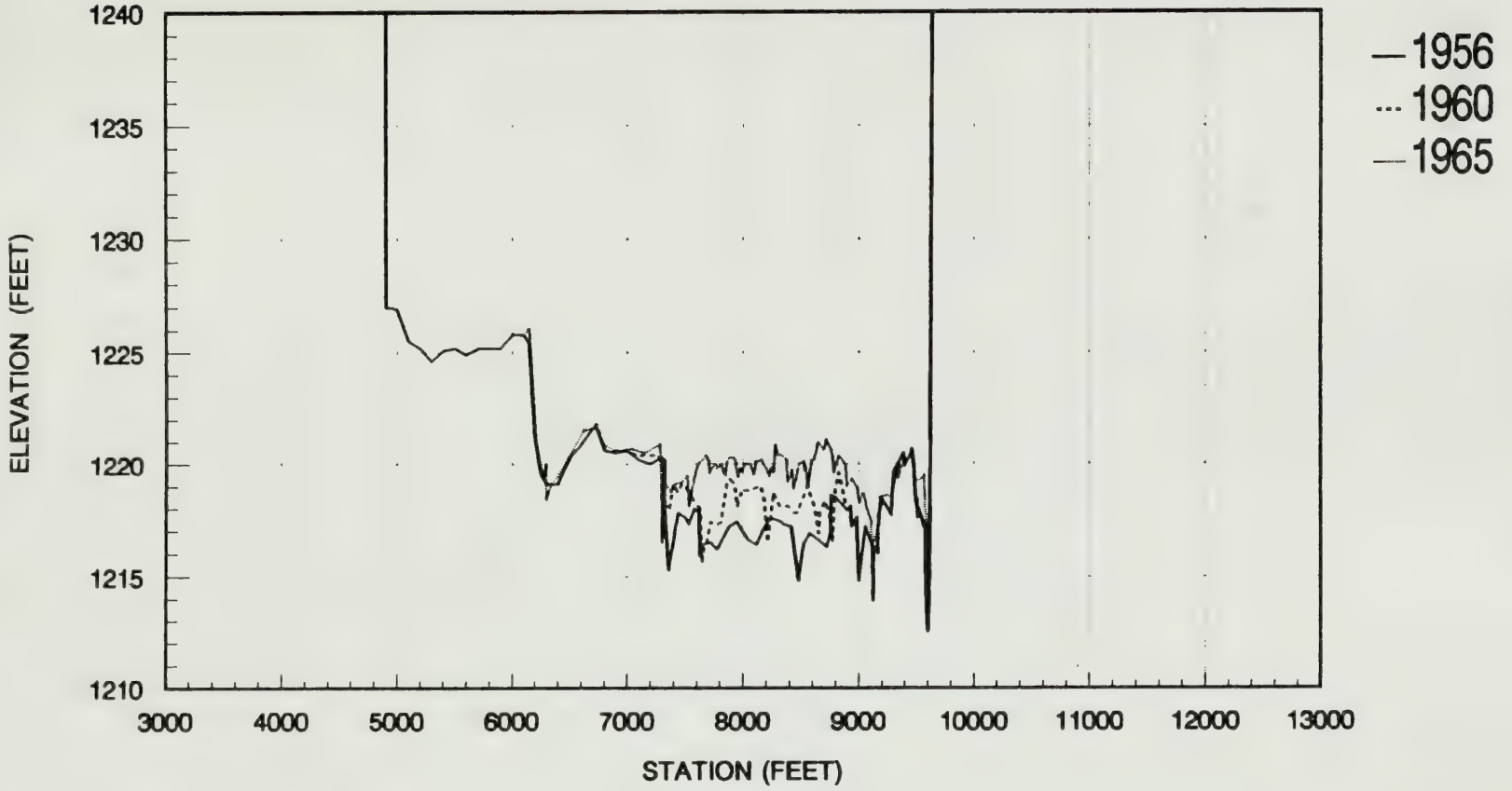


Plate III.5

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 0.8

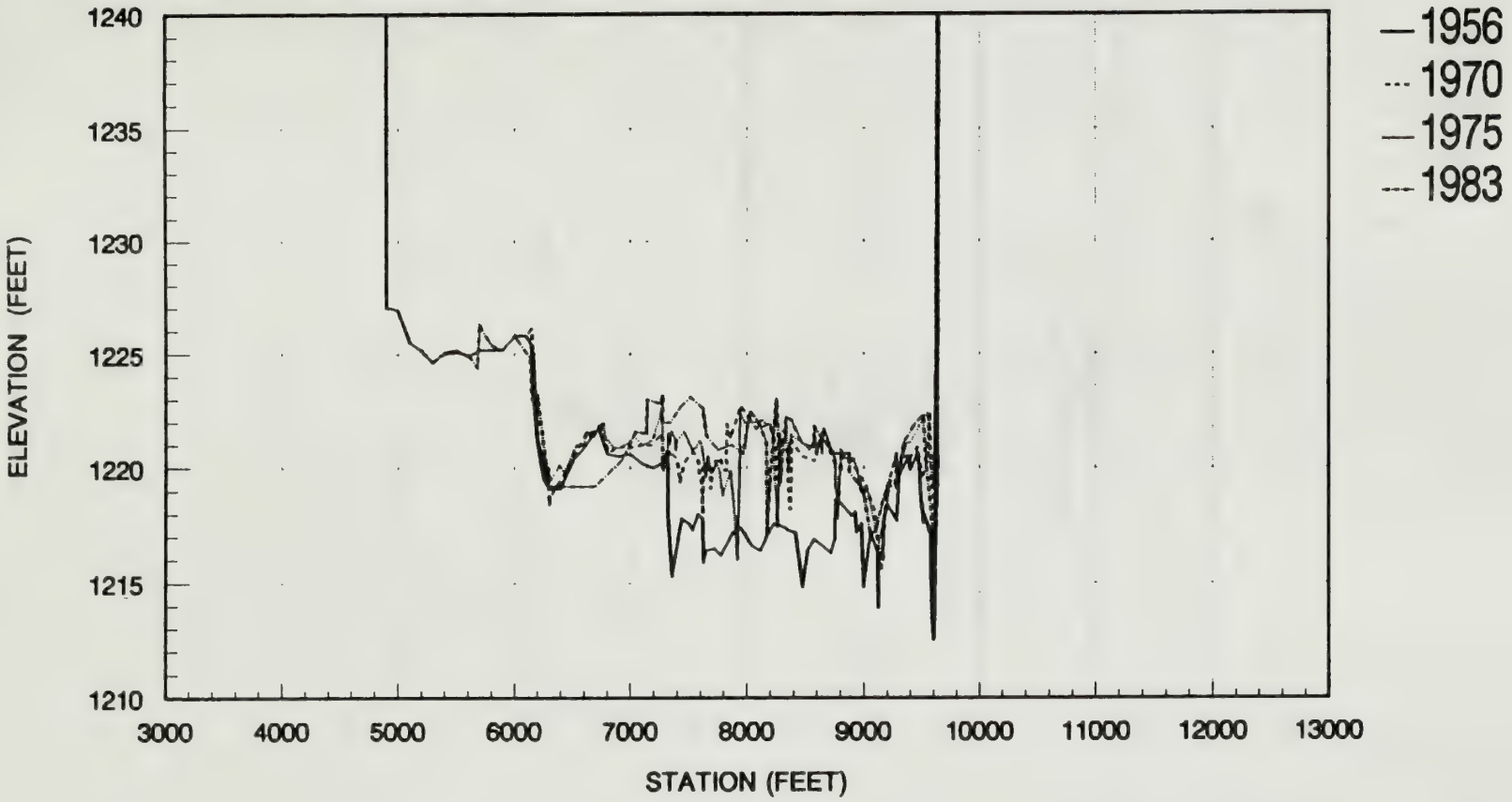


Plate III.6

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 1.1

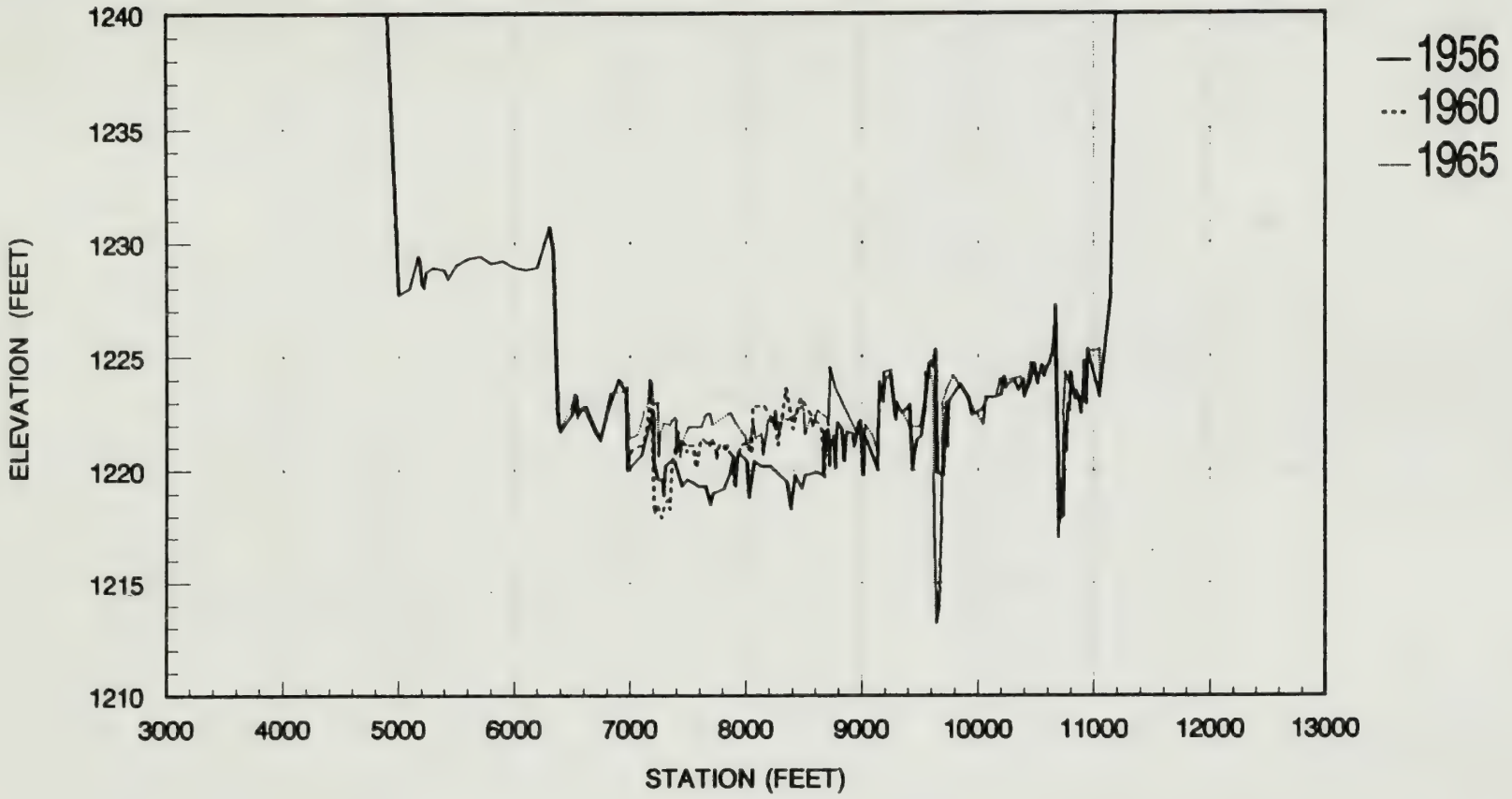


Plate III.7

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 1.1

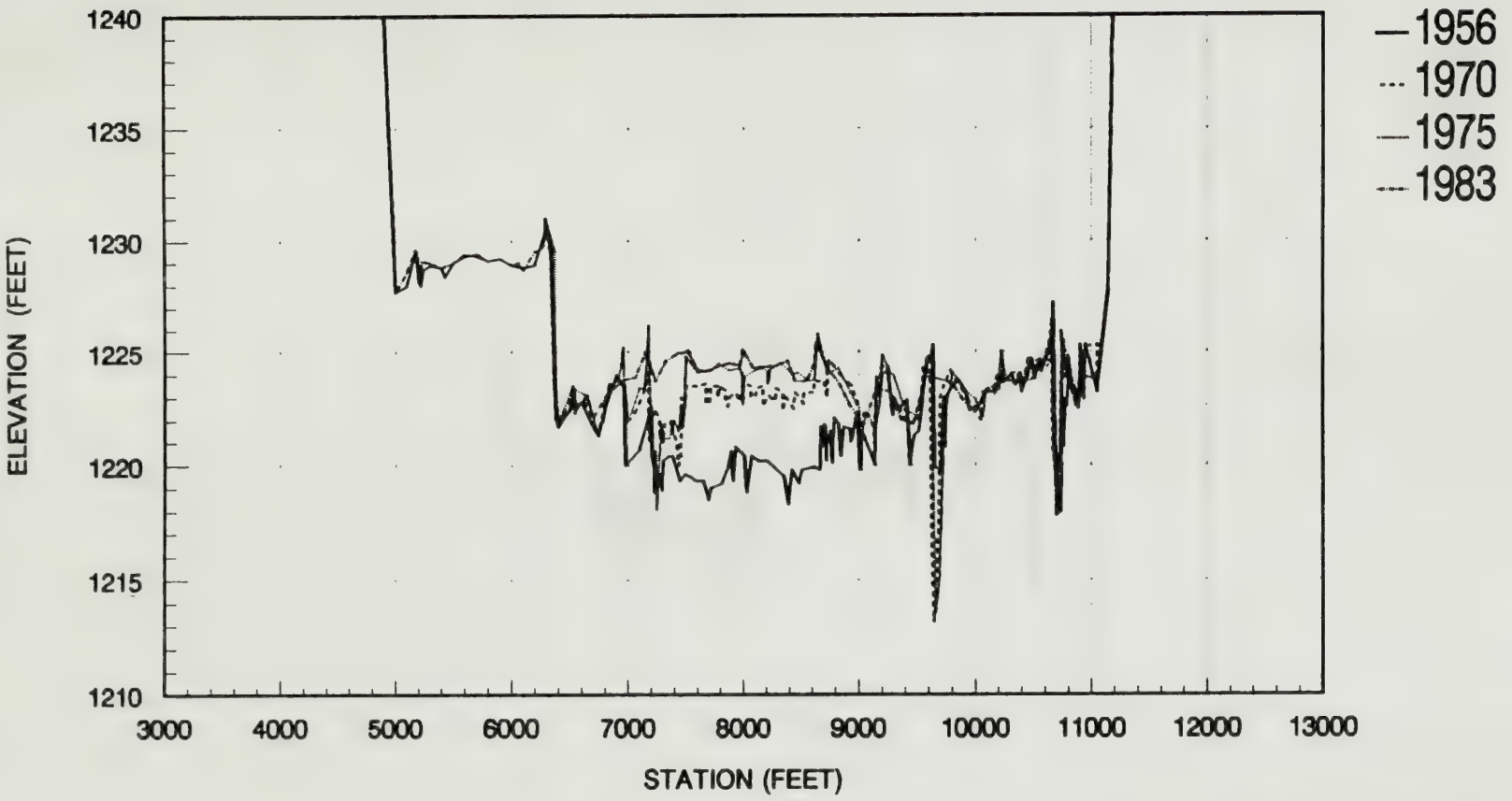


Plate III.8

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 1.4

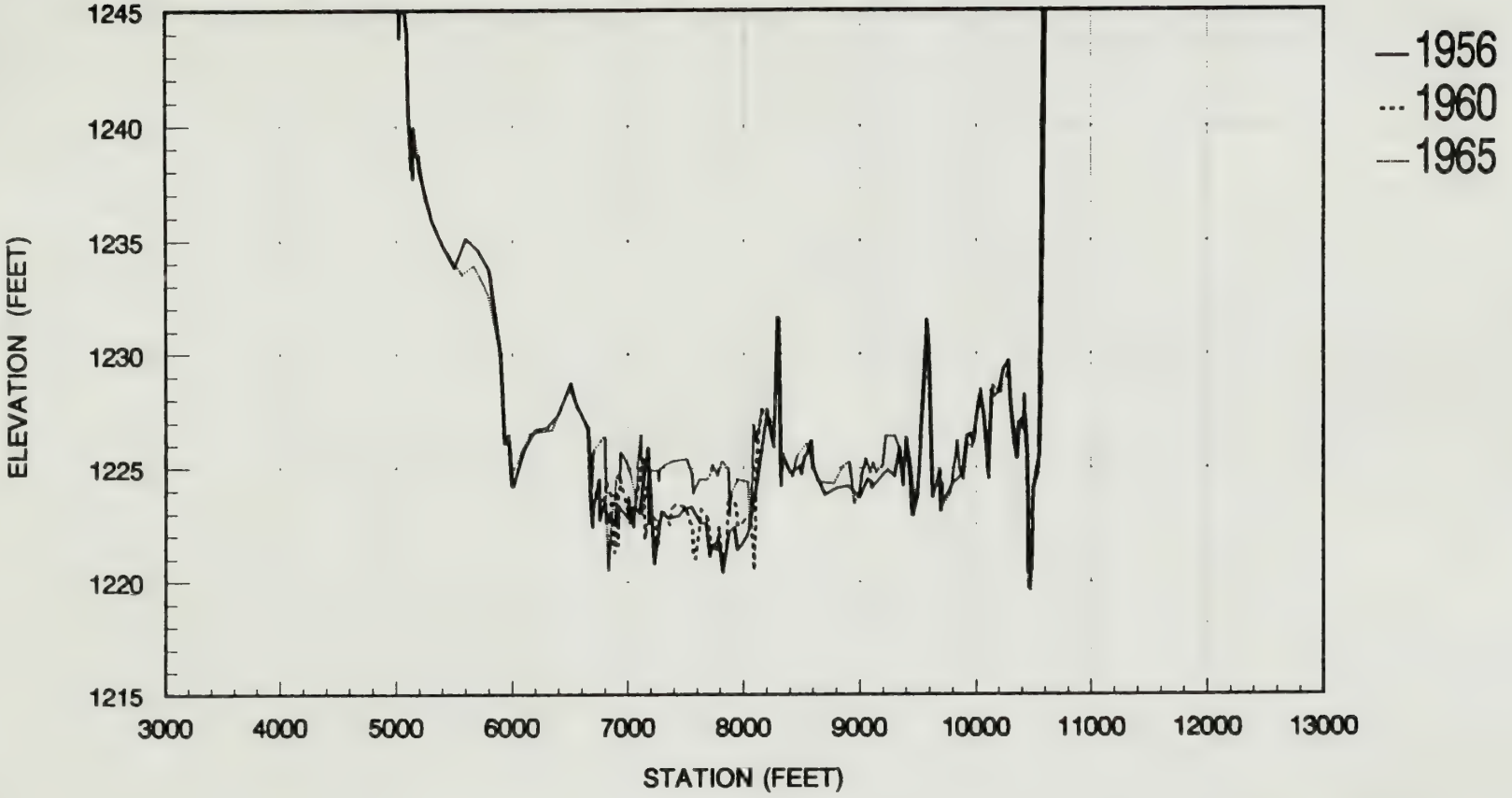


Plate III.9

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 1.4

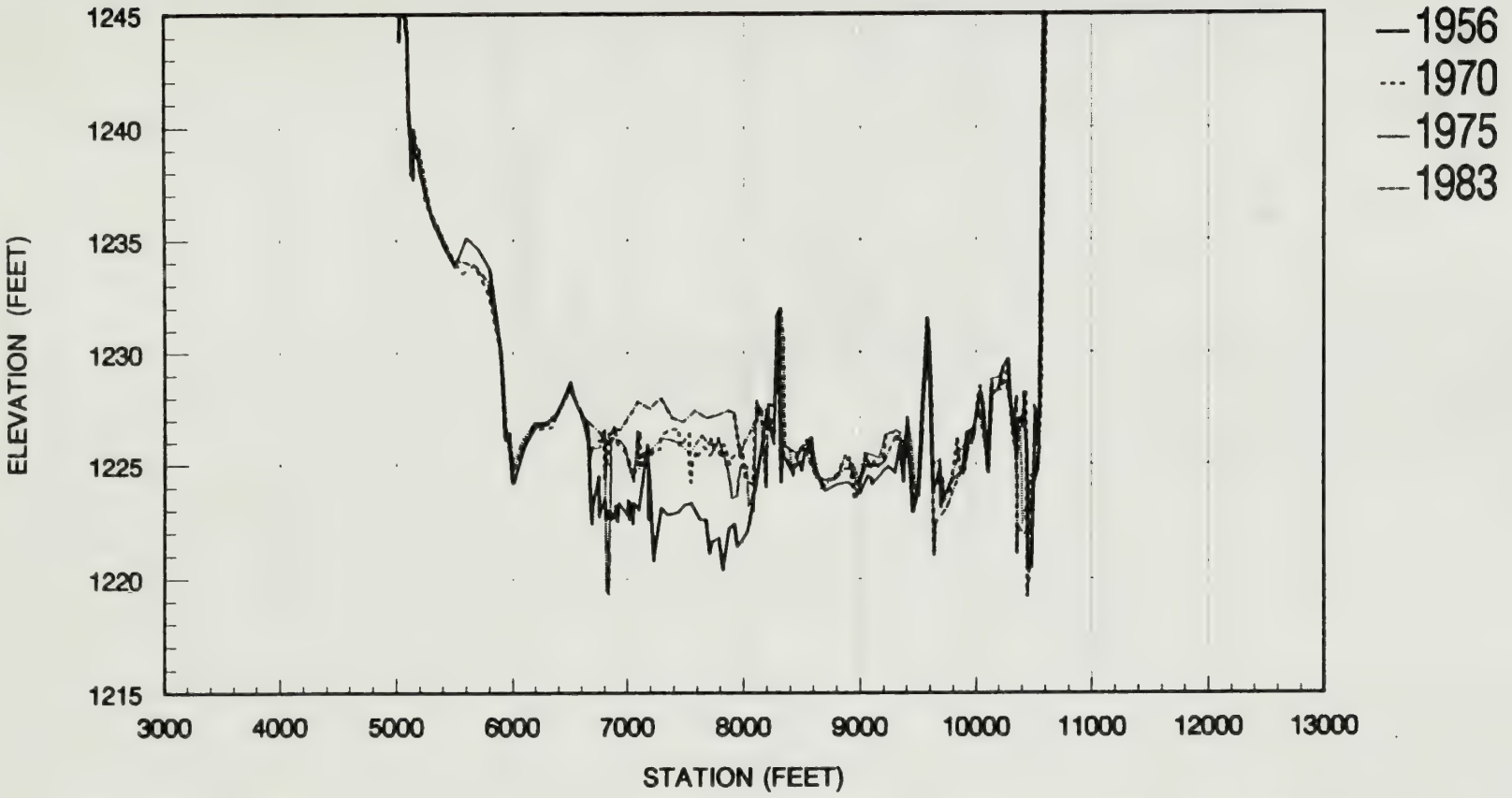


Plate III.10

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 1.9

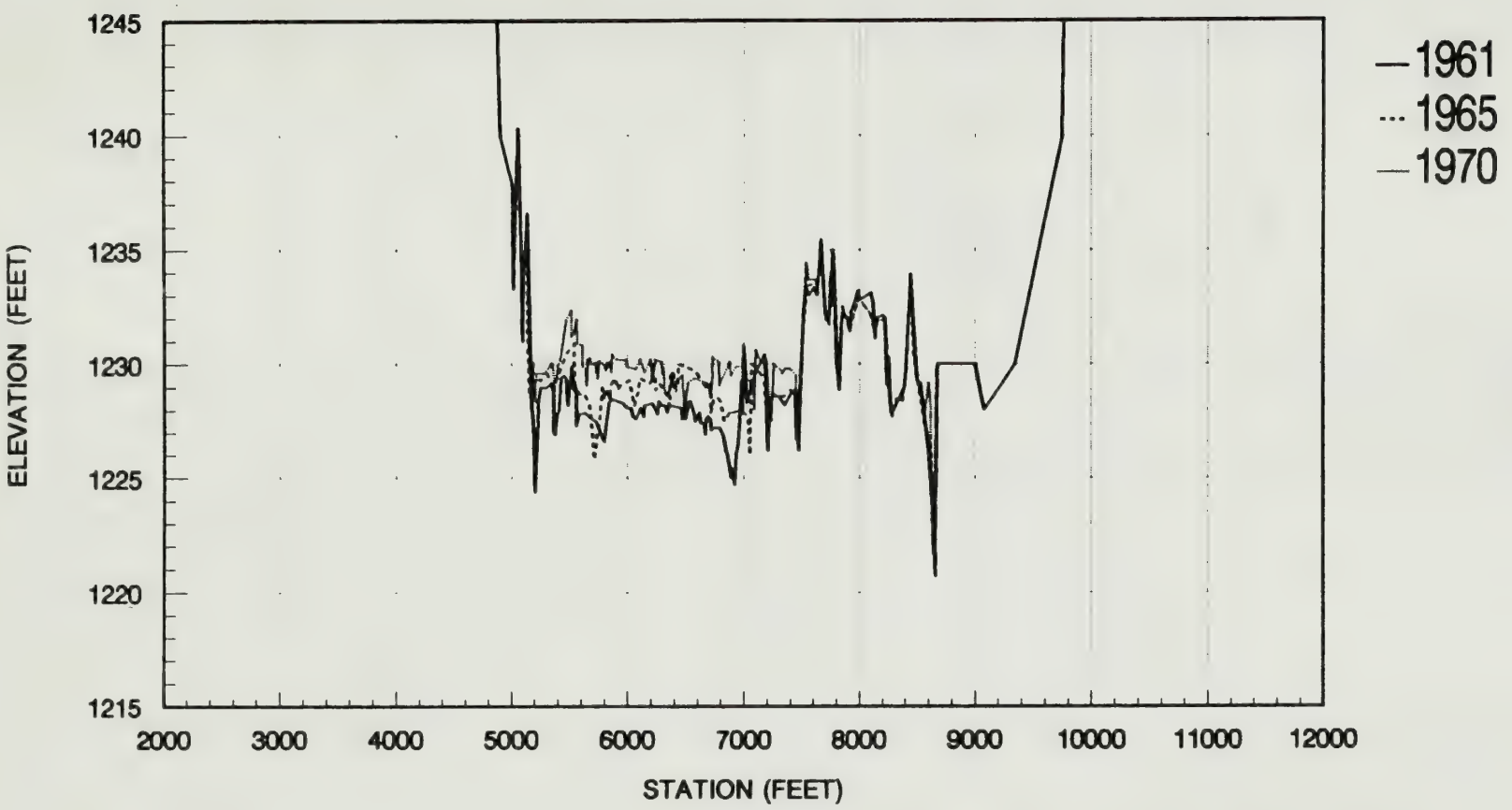


Plate III.11

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 1.9

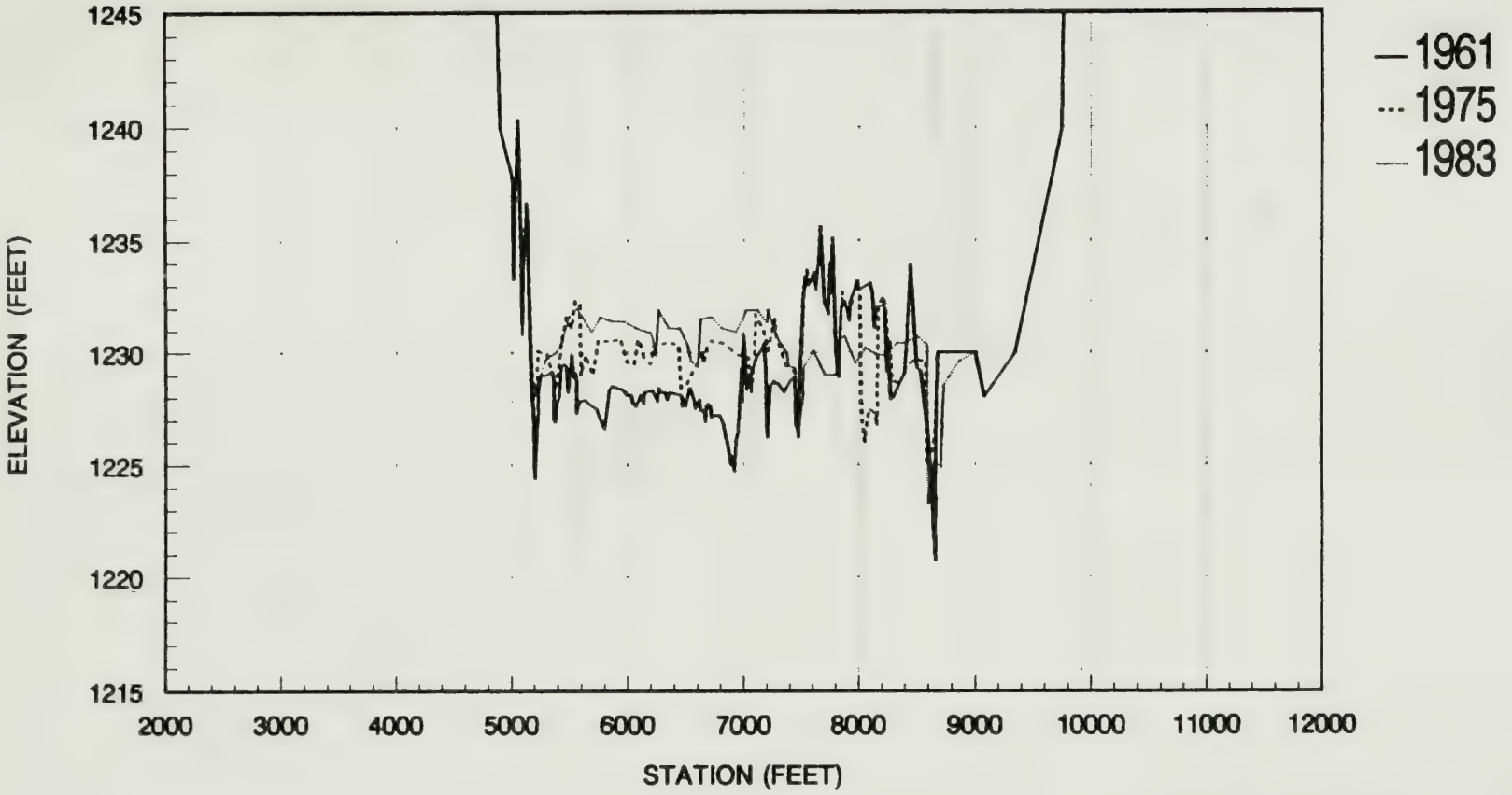


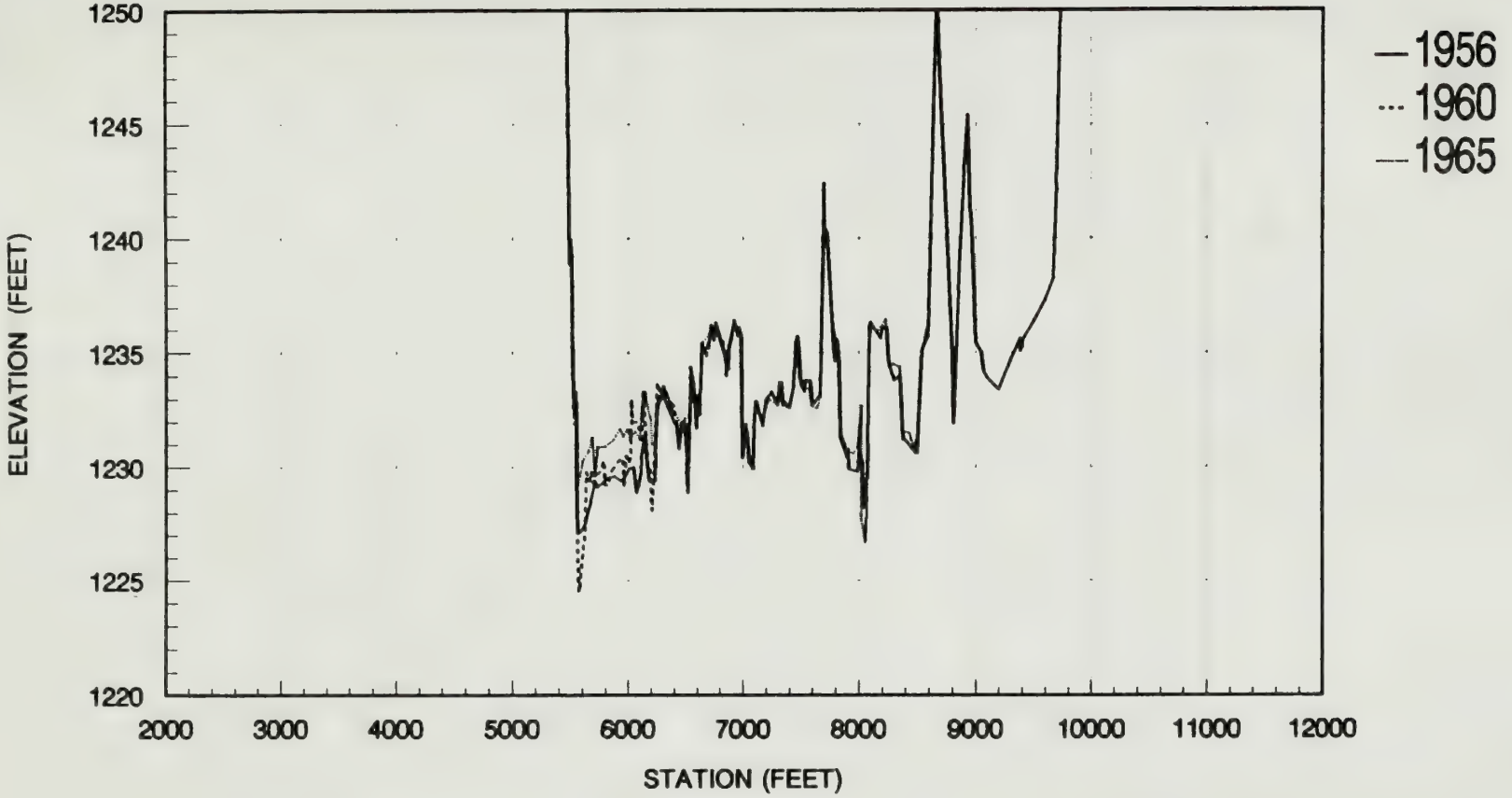
Plate III.12

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 2.4



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 2.4

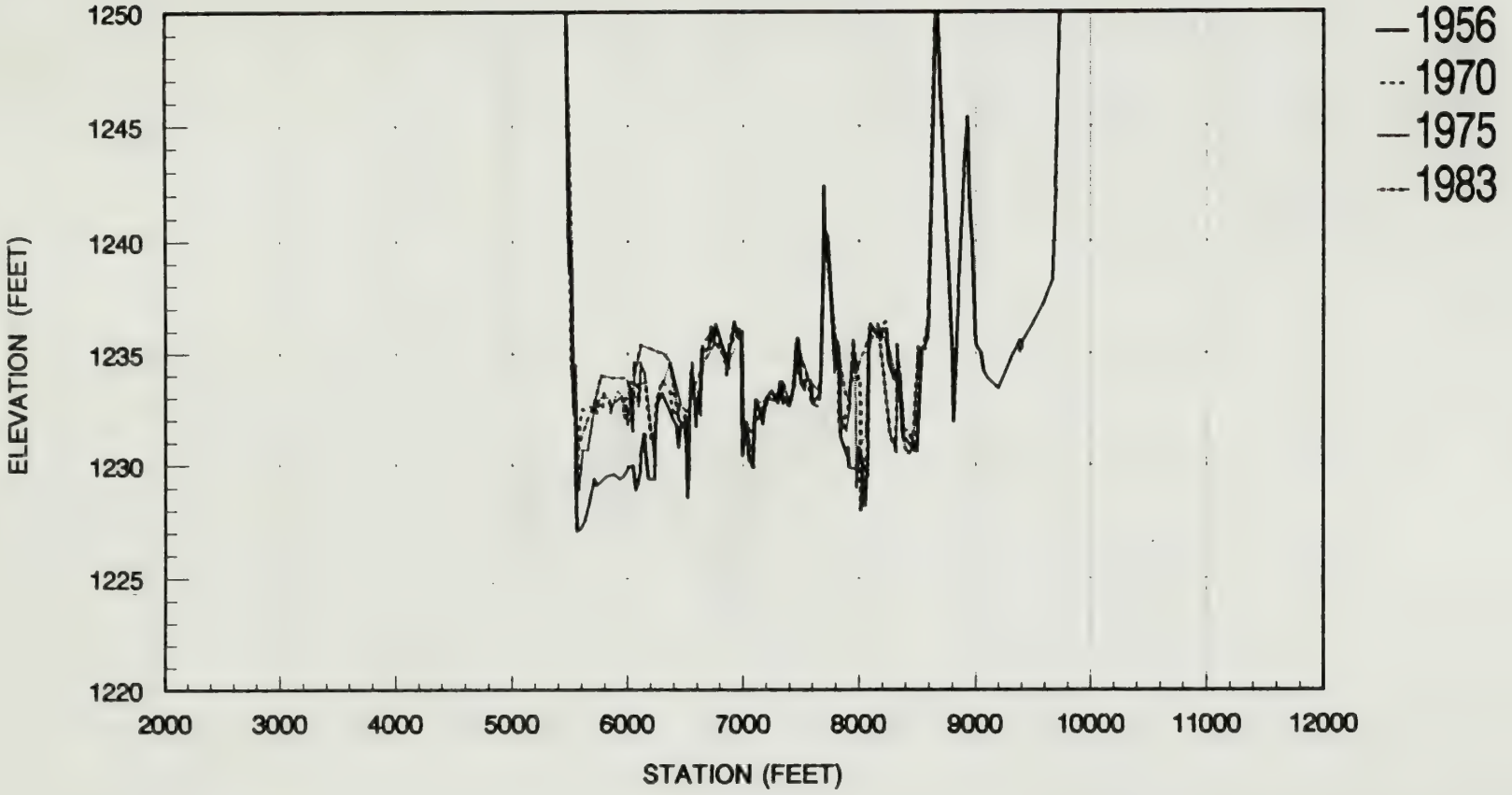


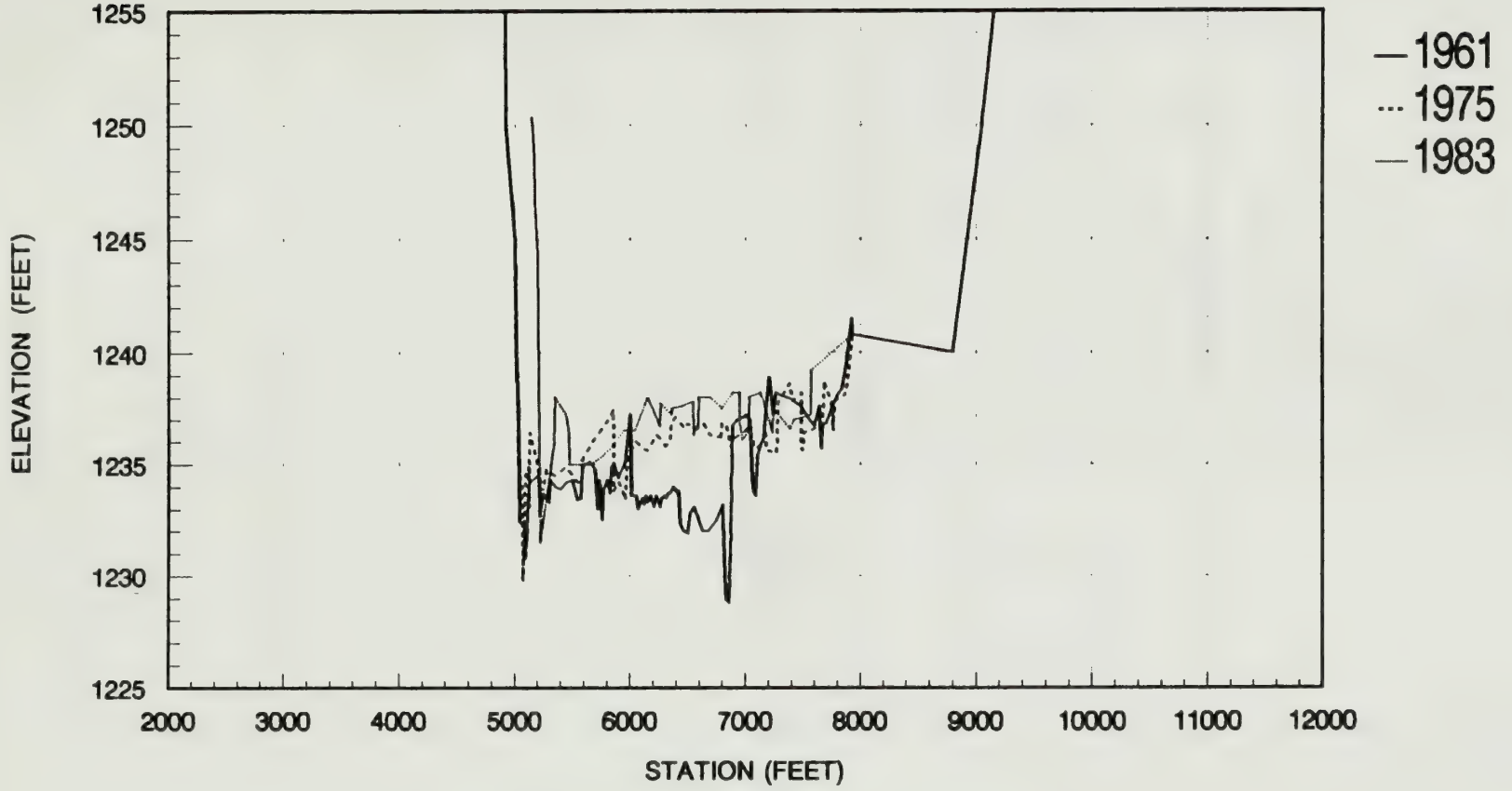
Plate III.14

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 3.0



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 3.6

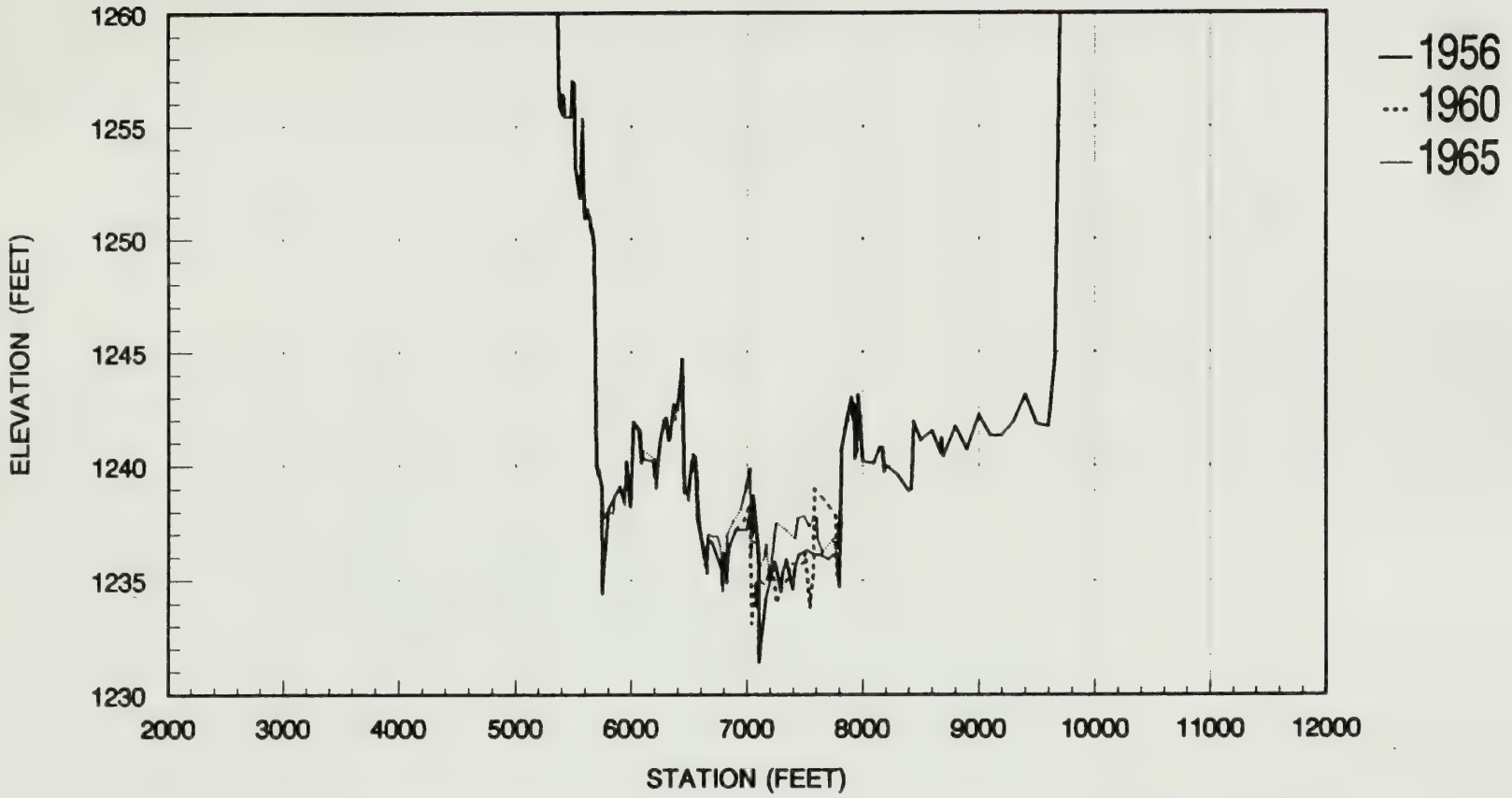


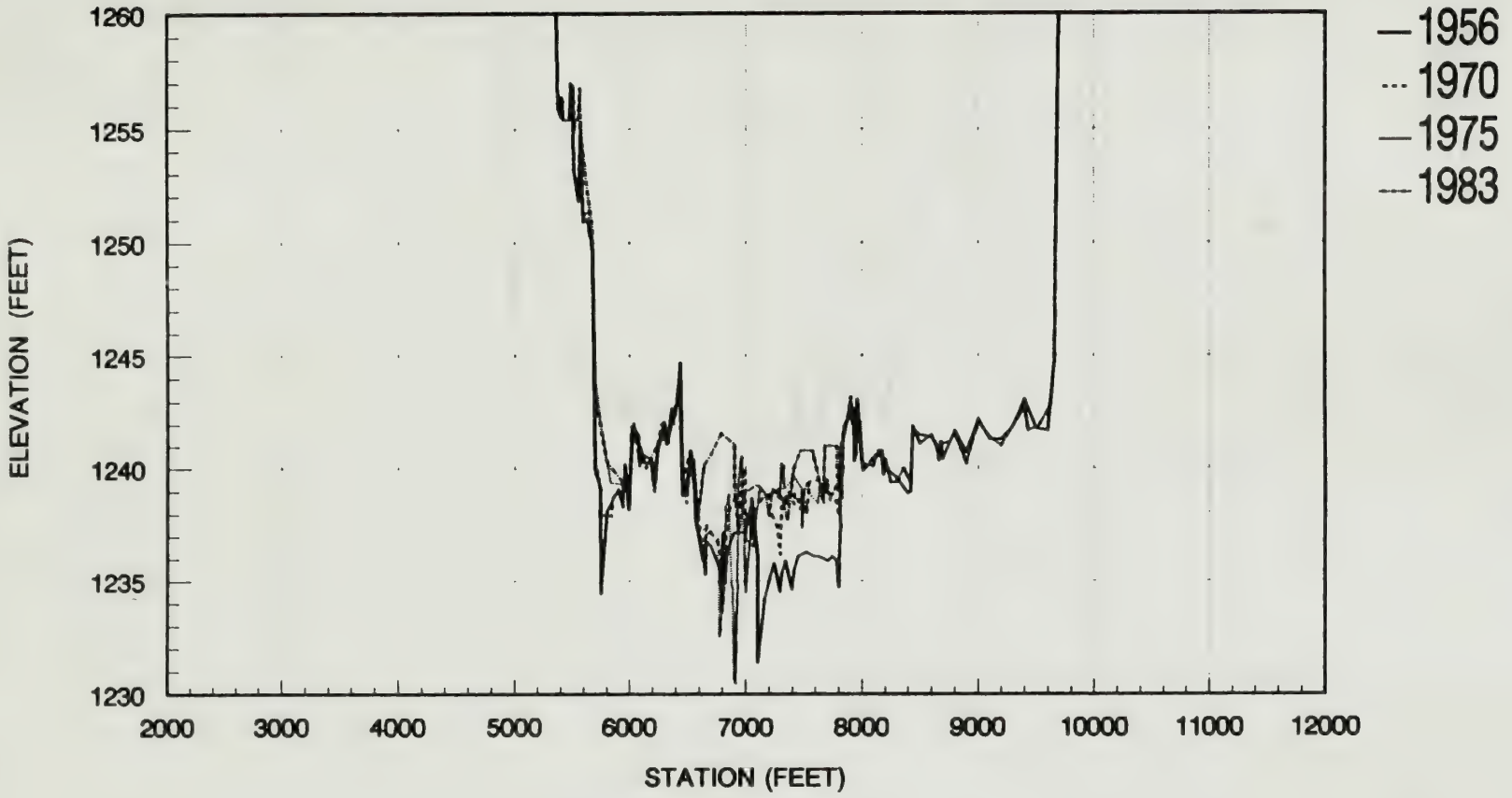
Plate III.17

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 3.6



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 4.0

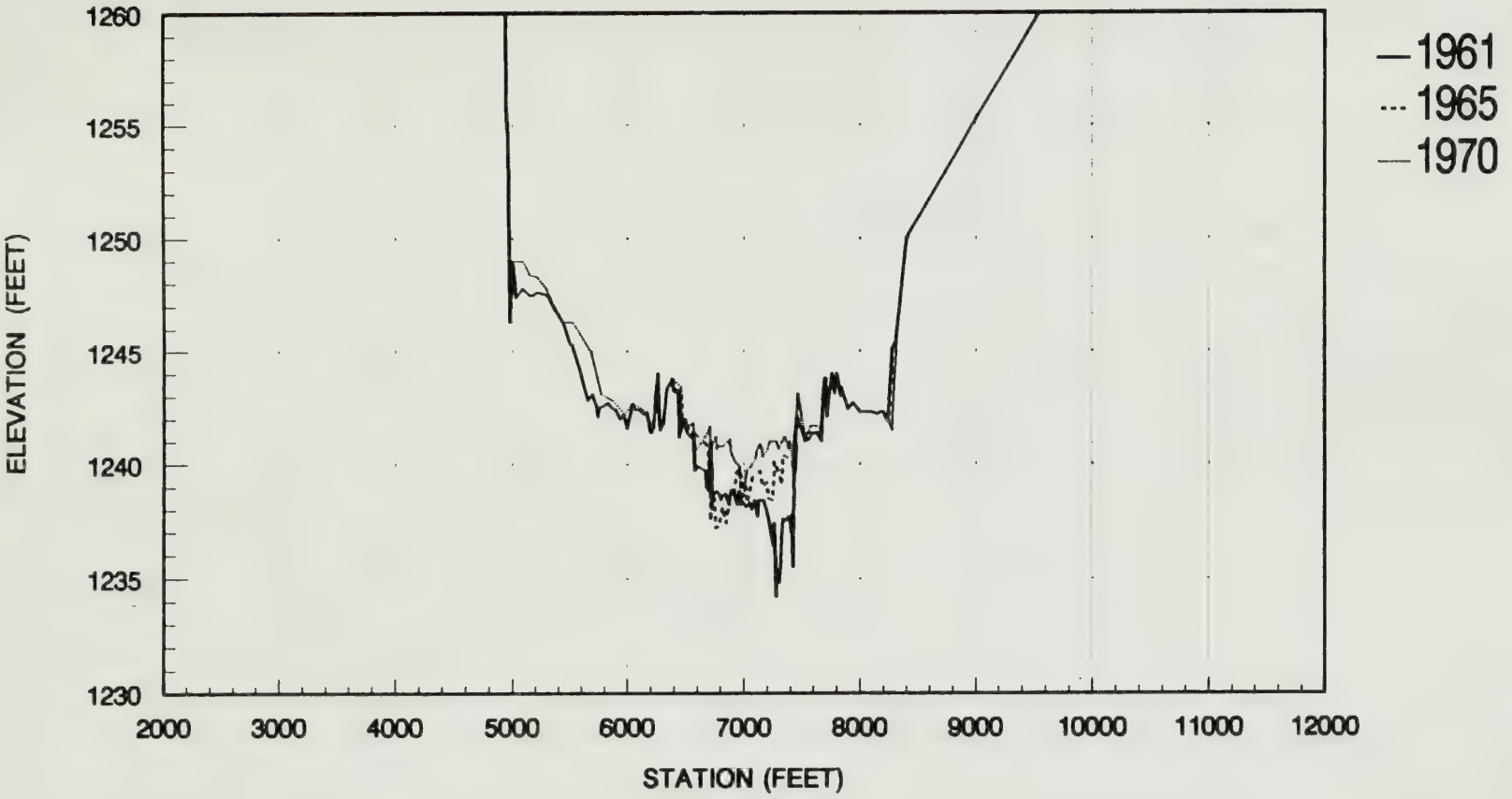


Plate III.19

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 4.0

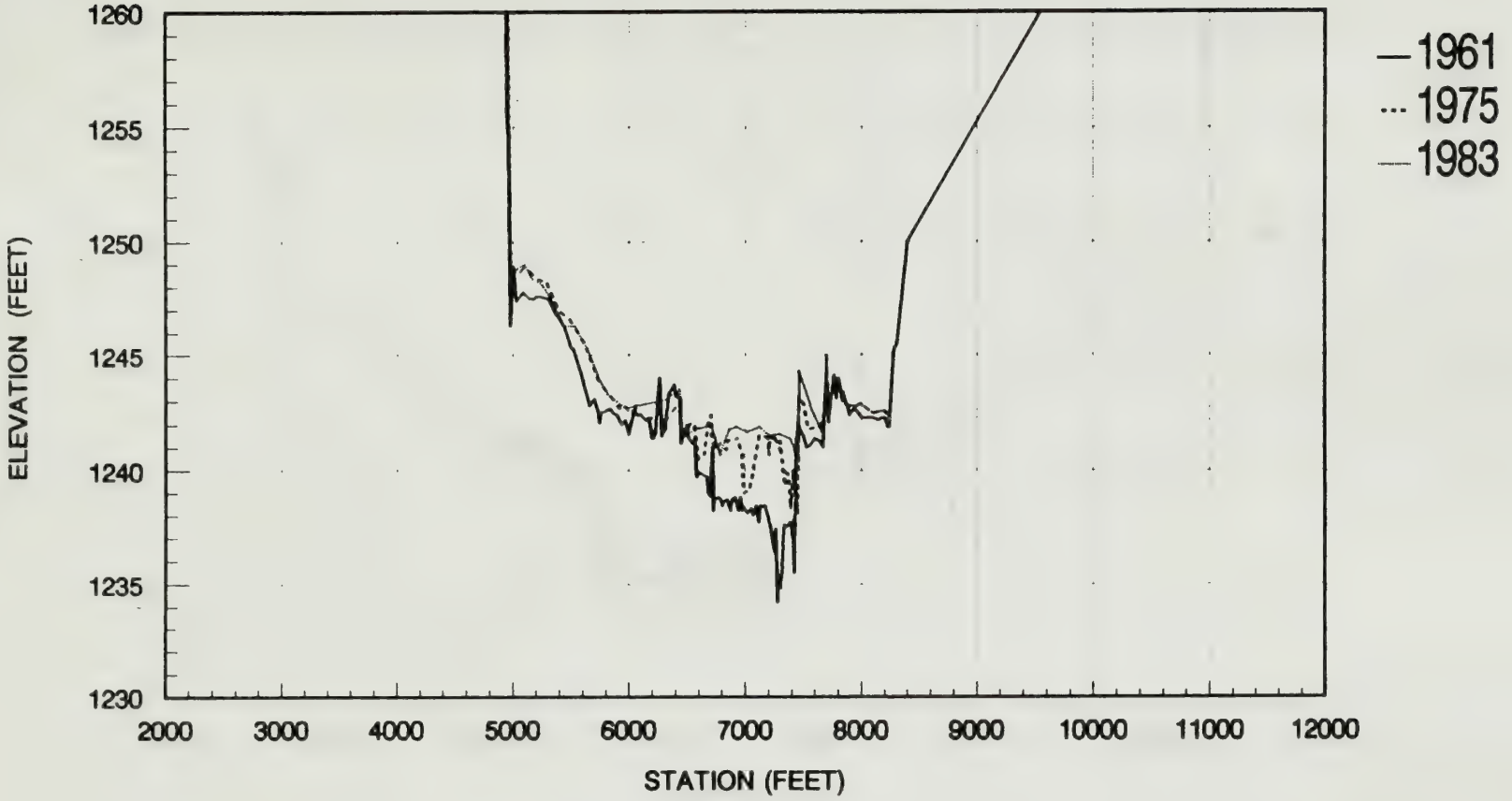


Plate III.20

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 4.4

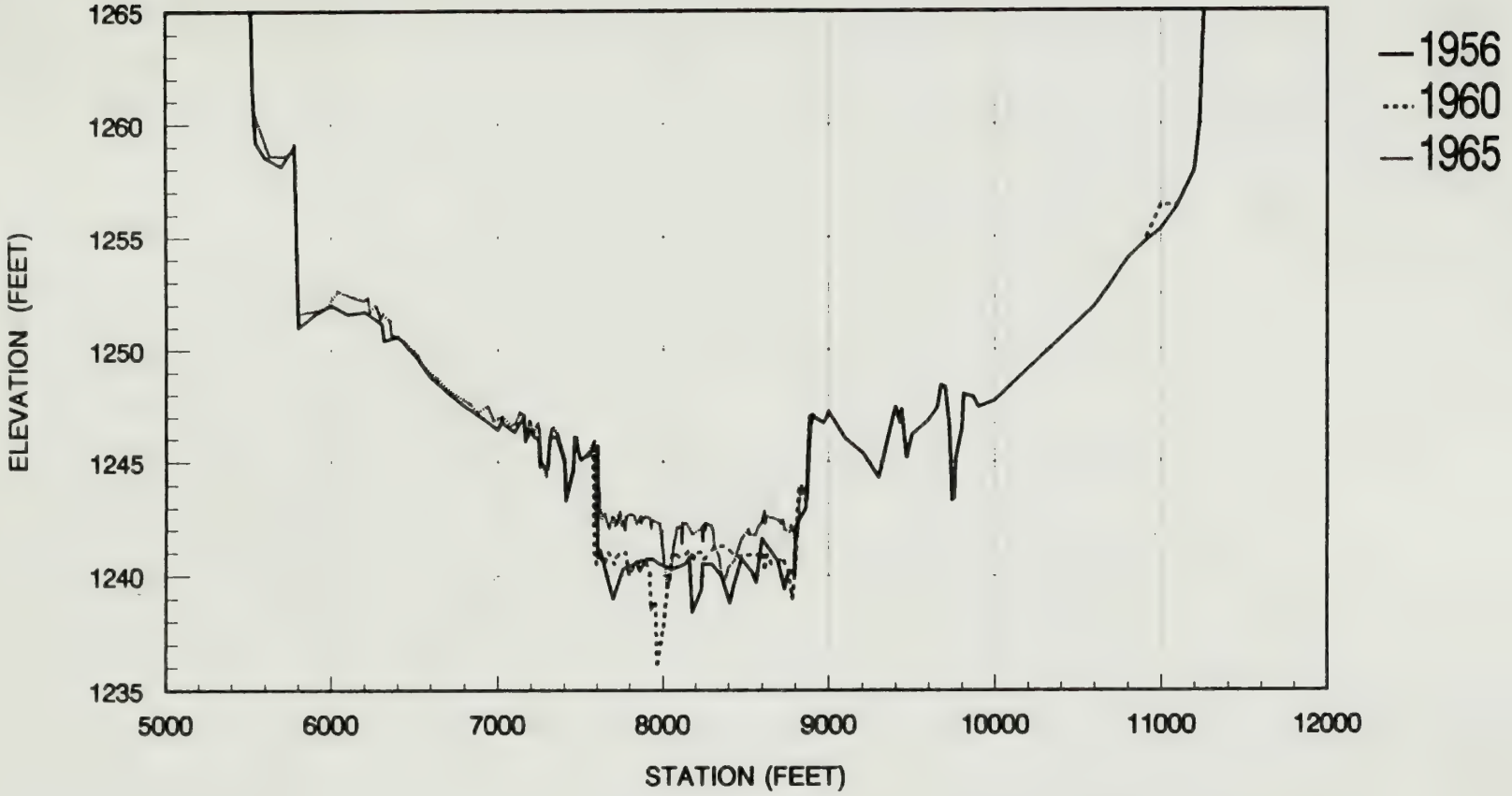


Plate III.21

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 4.4

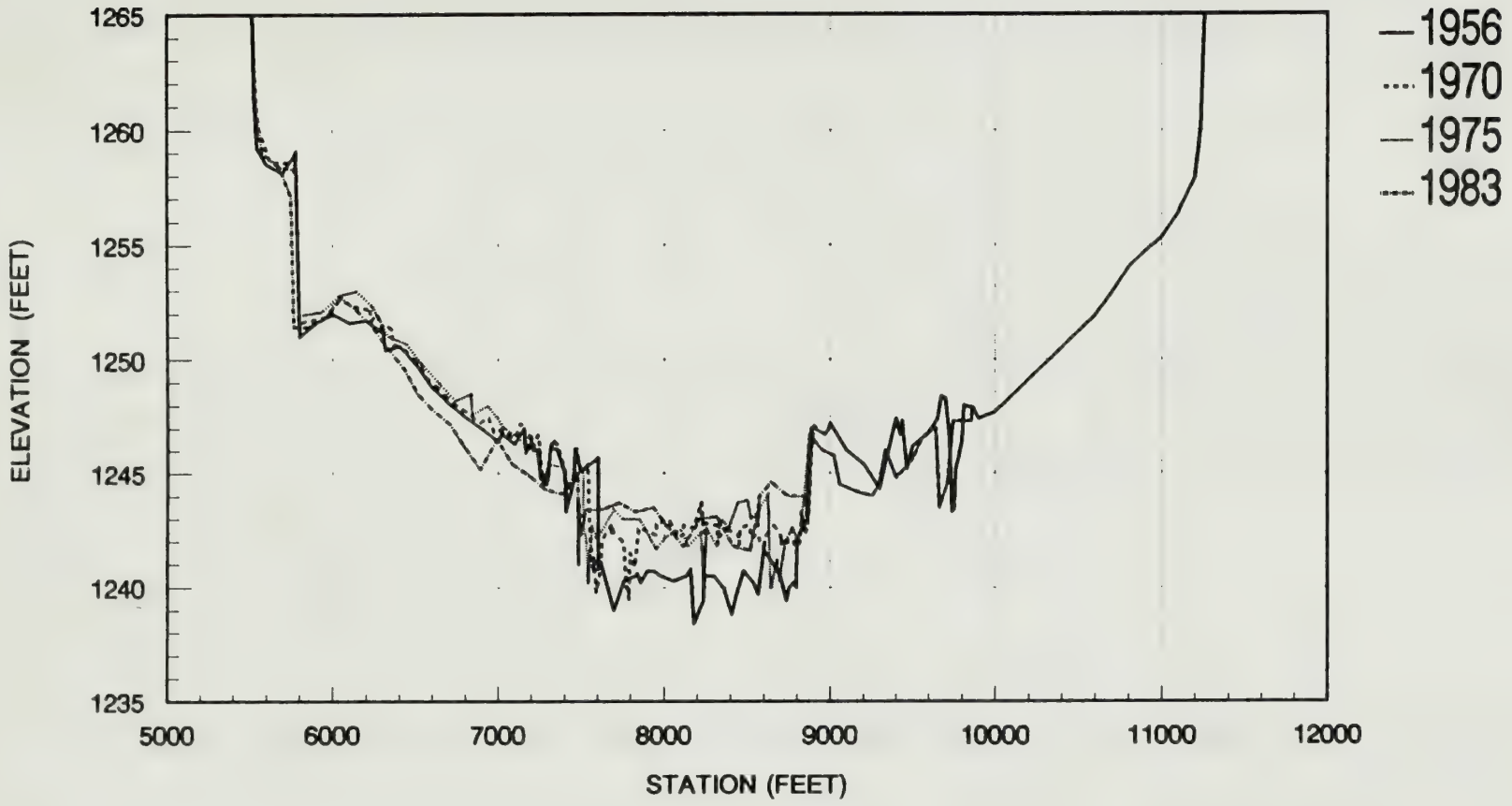


Plate III.22

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 5.2

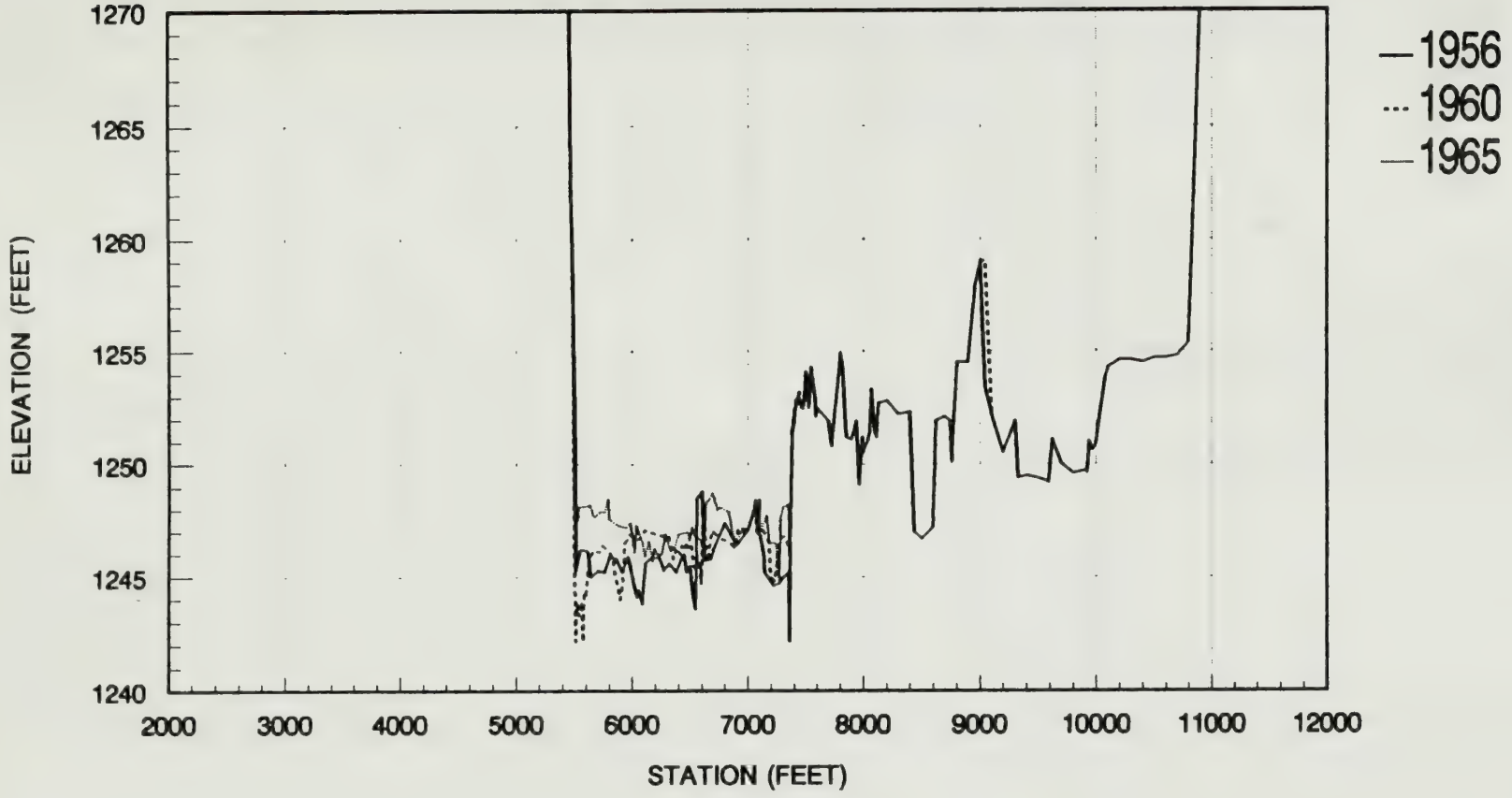


Plate III.23

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 5.2

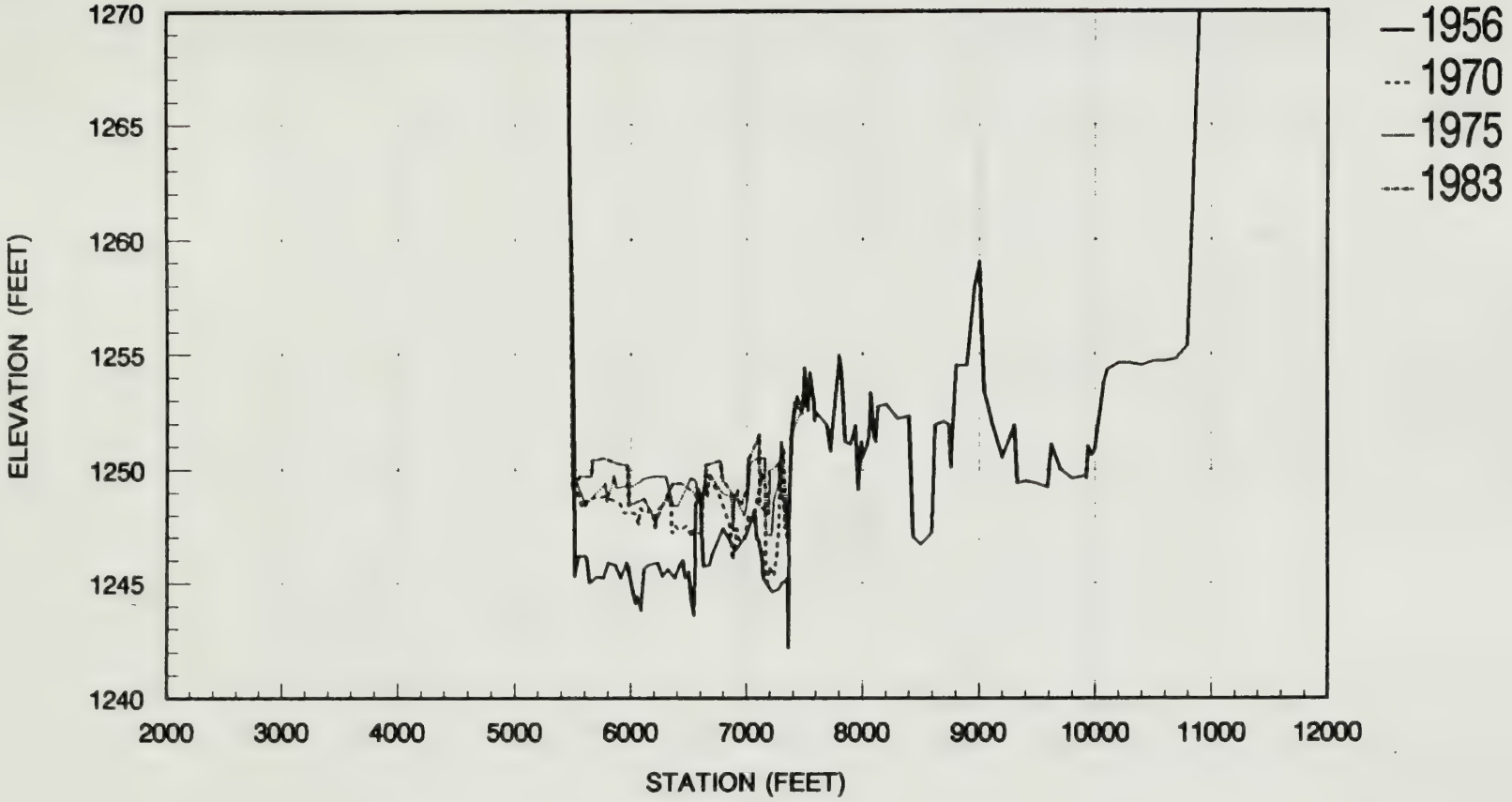


Plate III.24

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 6.0

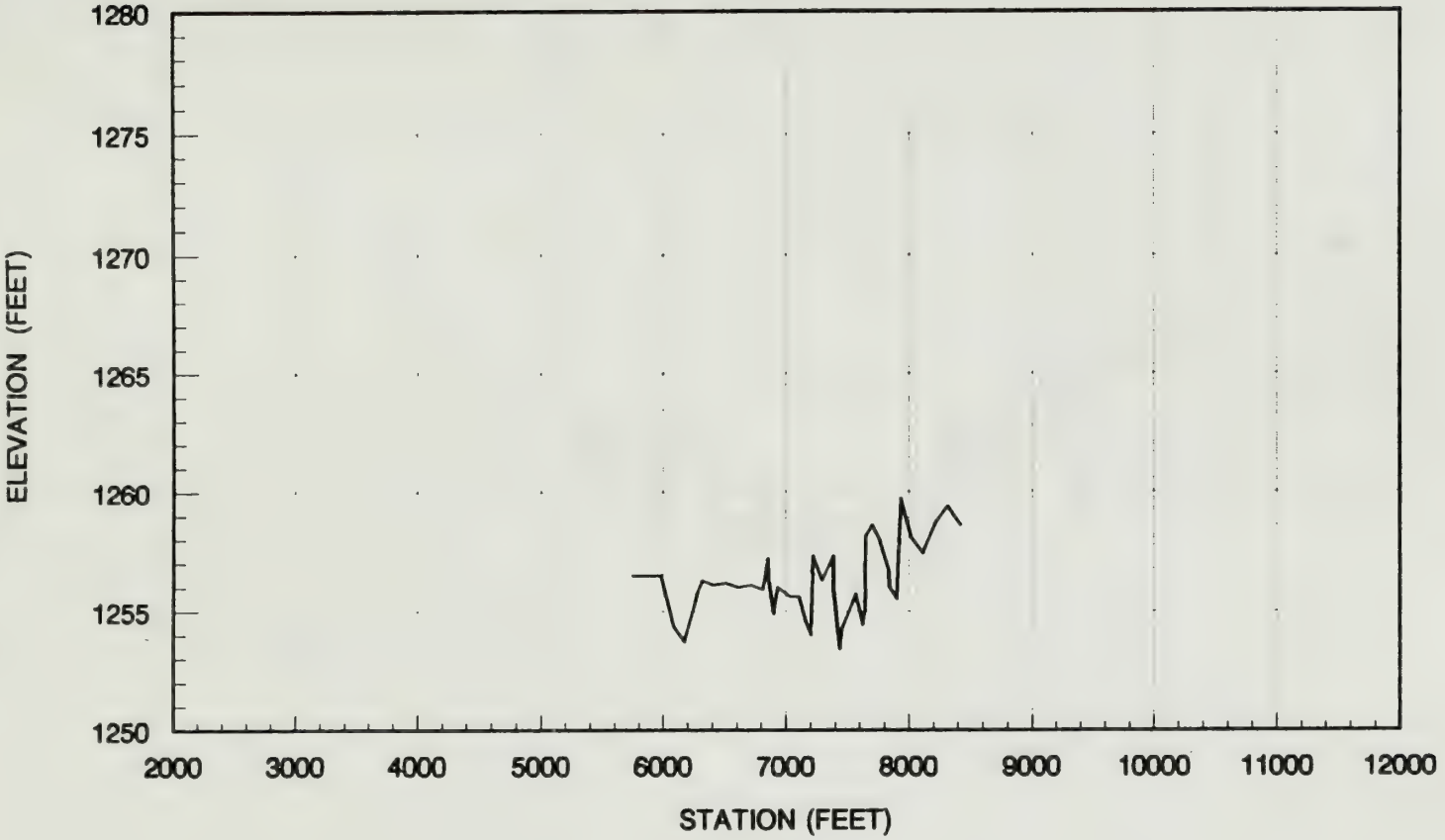


Plate III.25

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 6.9

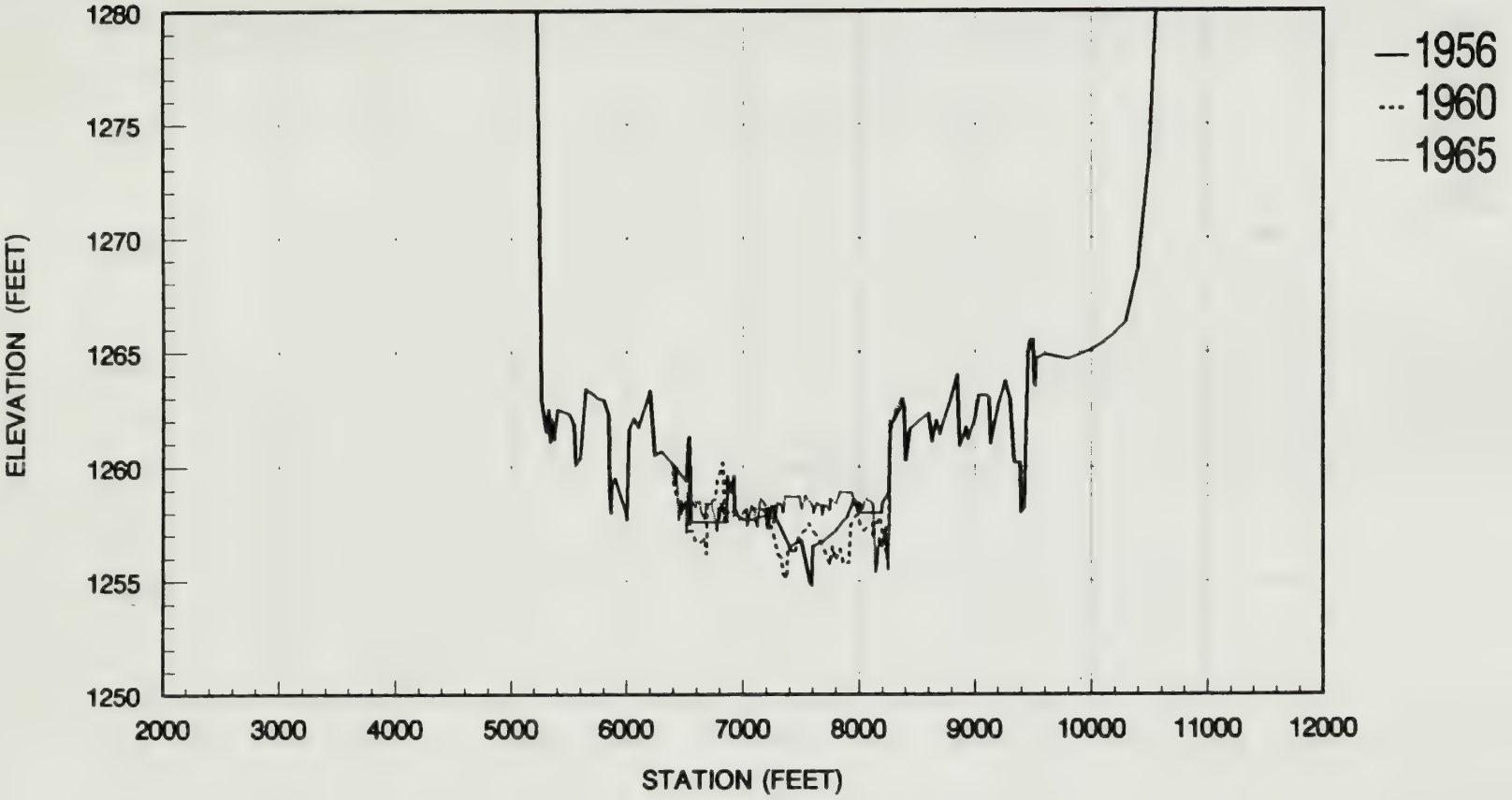


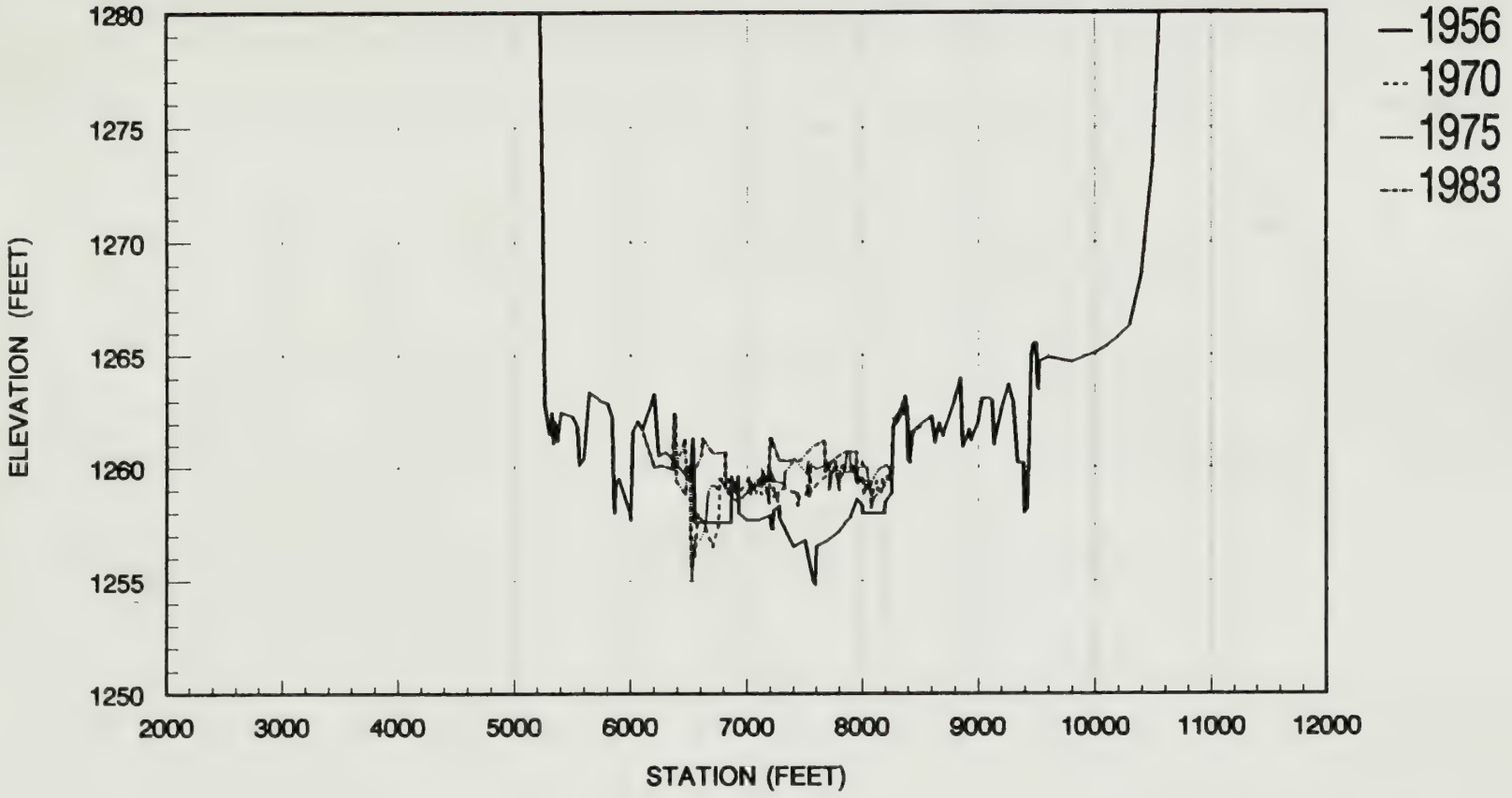
Plate III.26

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 6.9



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 8.0

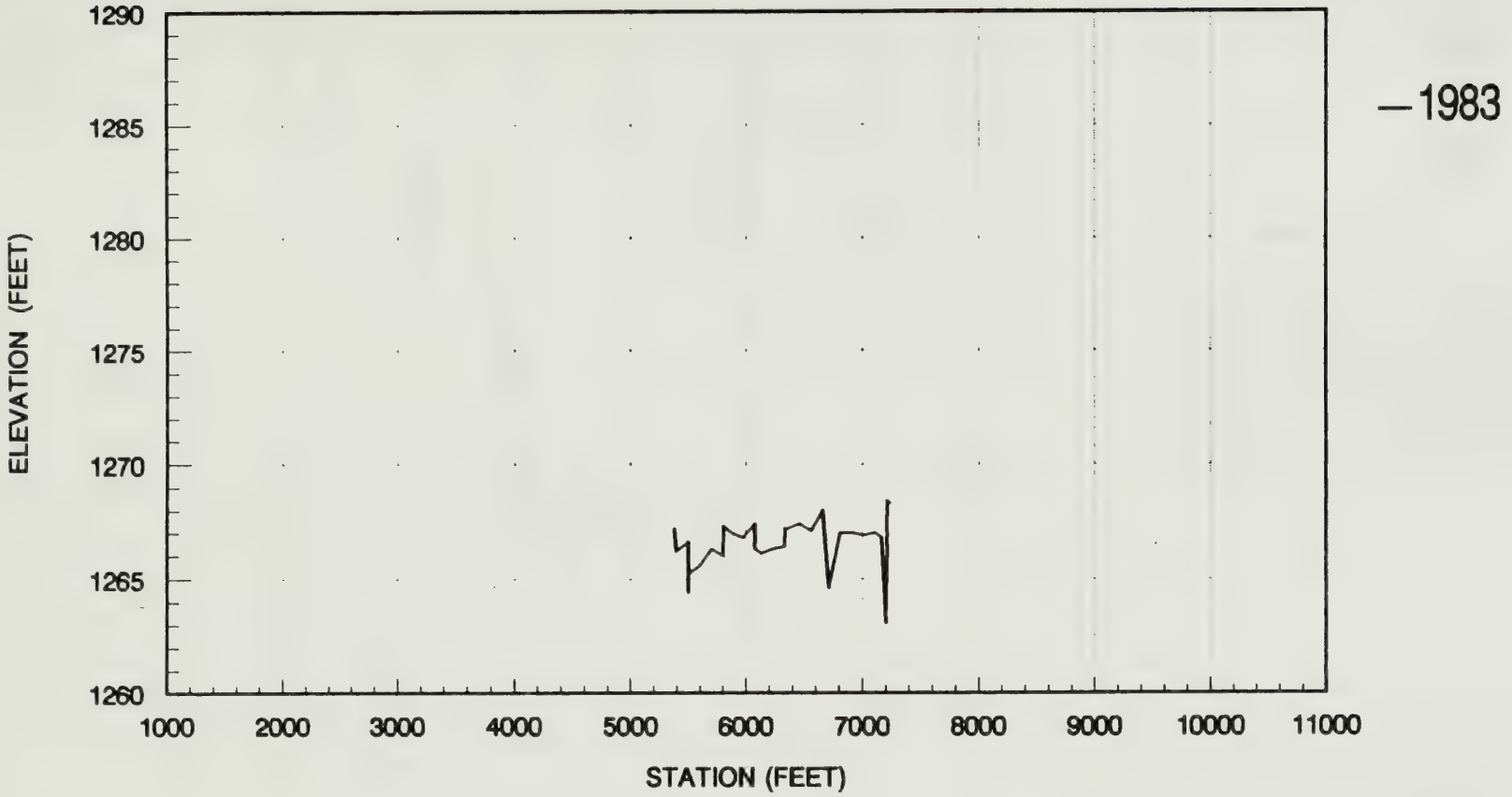


Plate III.28

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 9.0

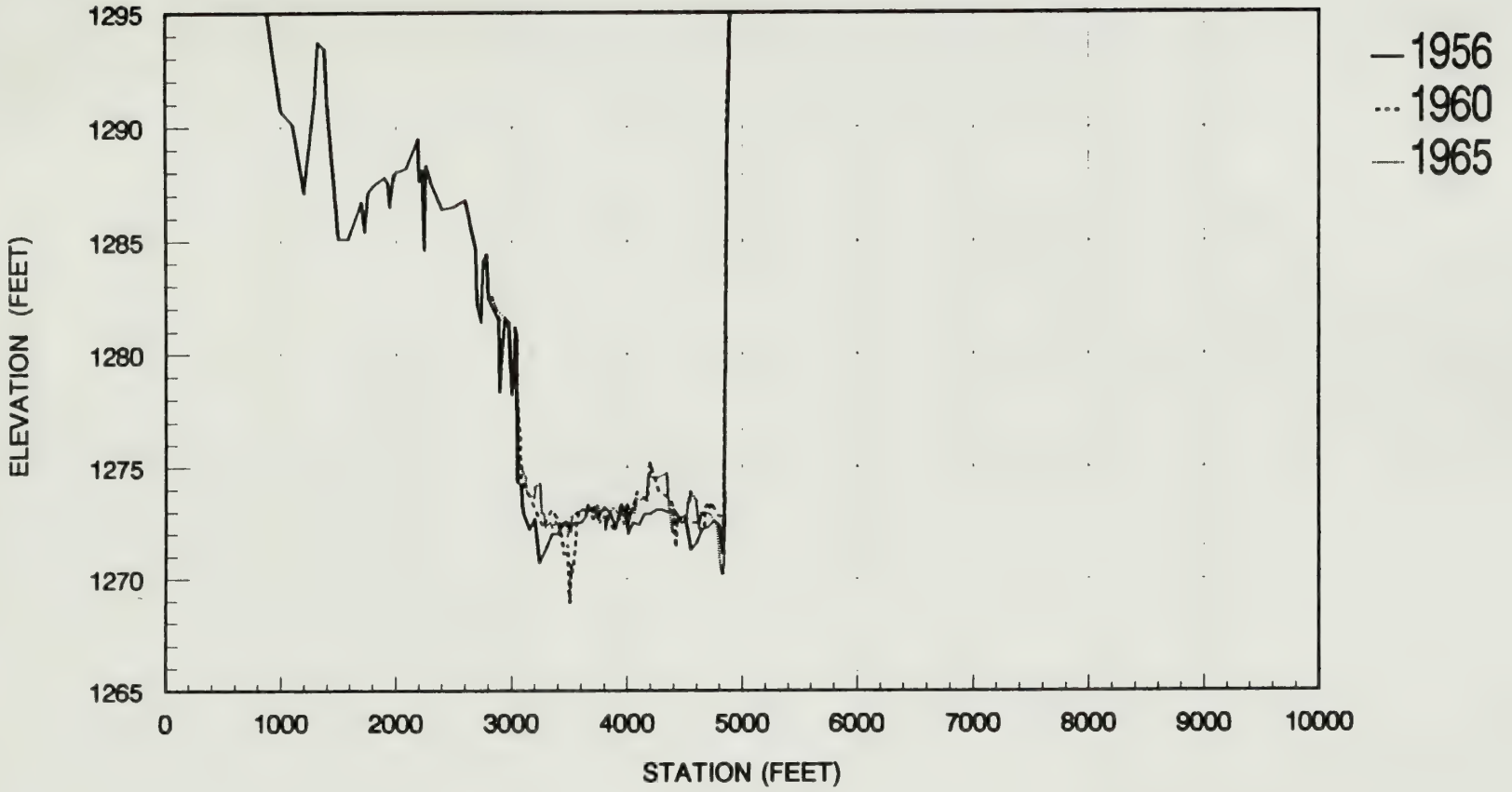


Plate III.29

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N 9.0

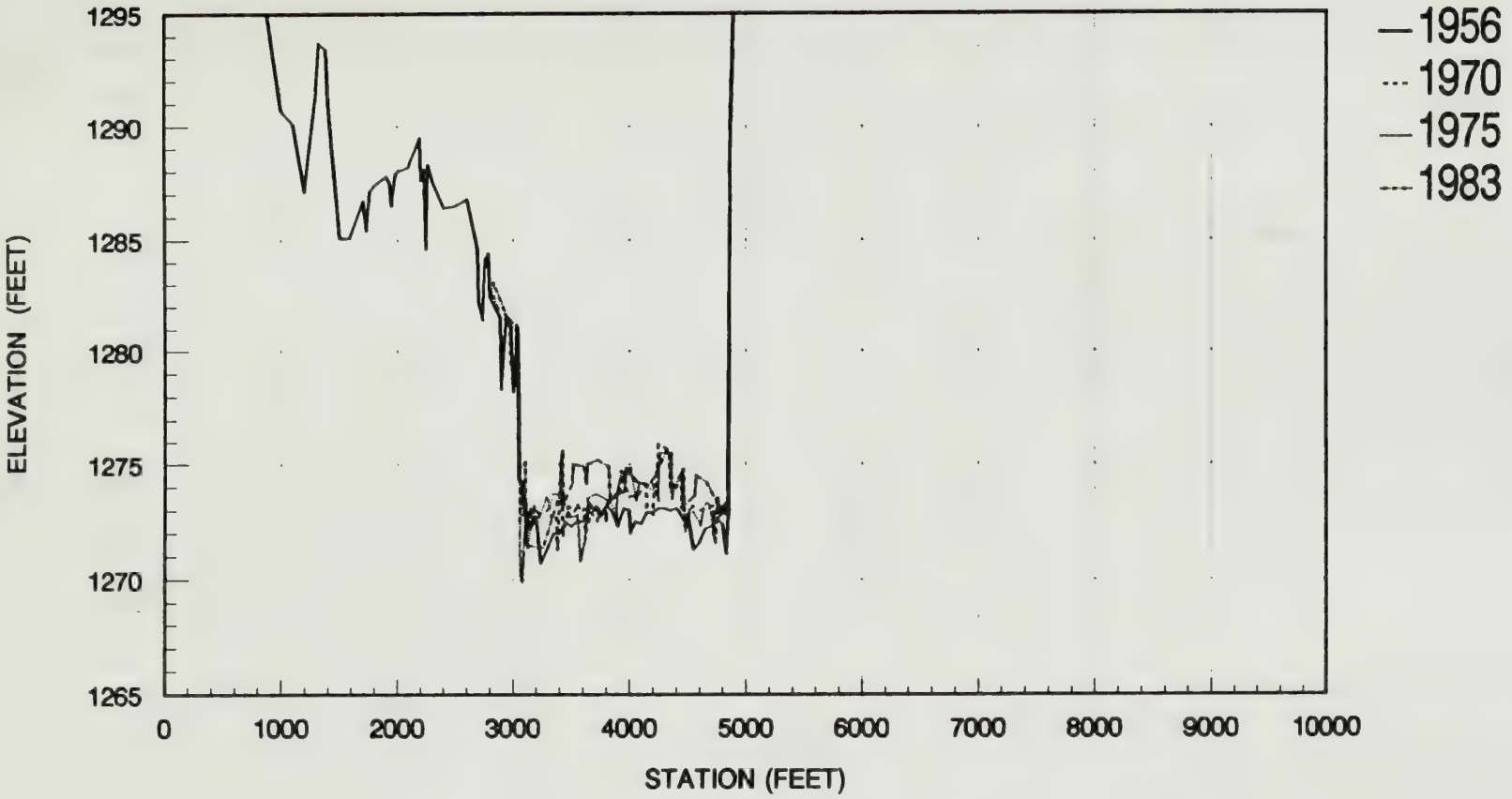


Plate III.30

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N10.5

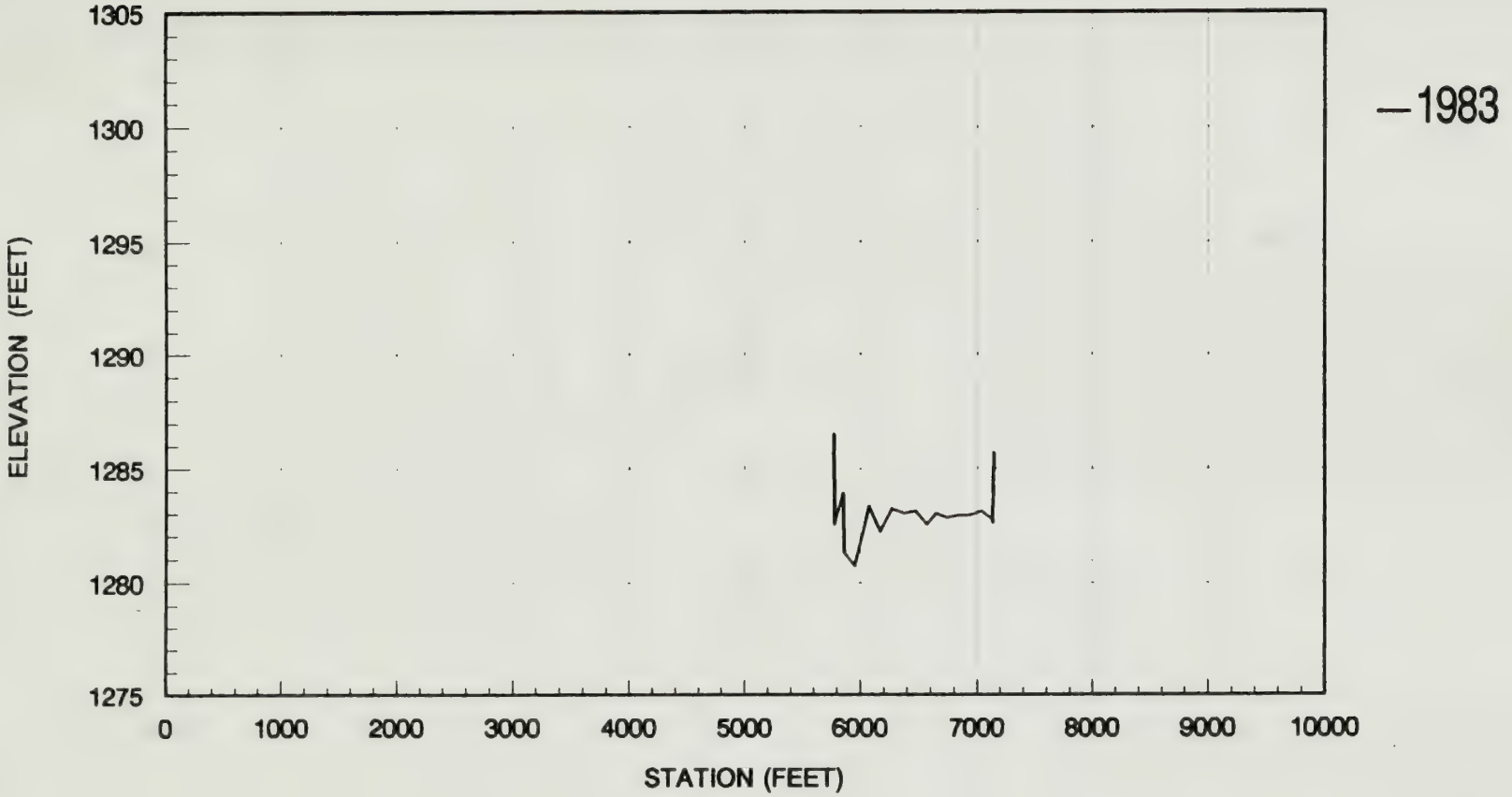


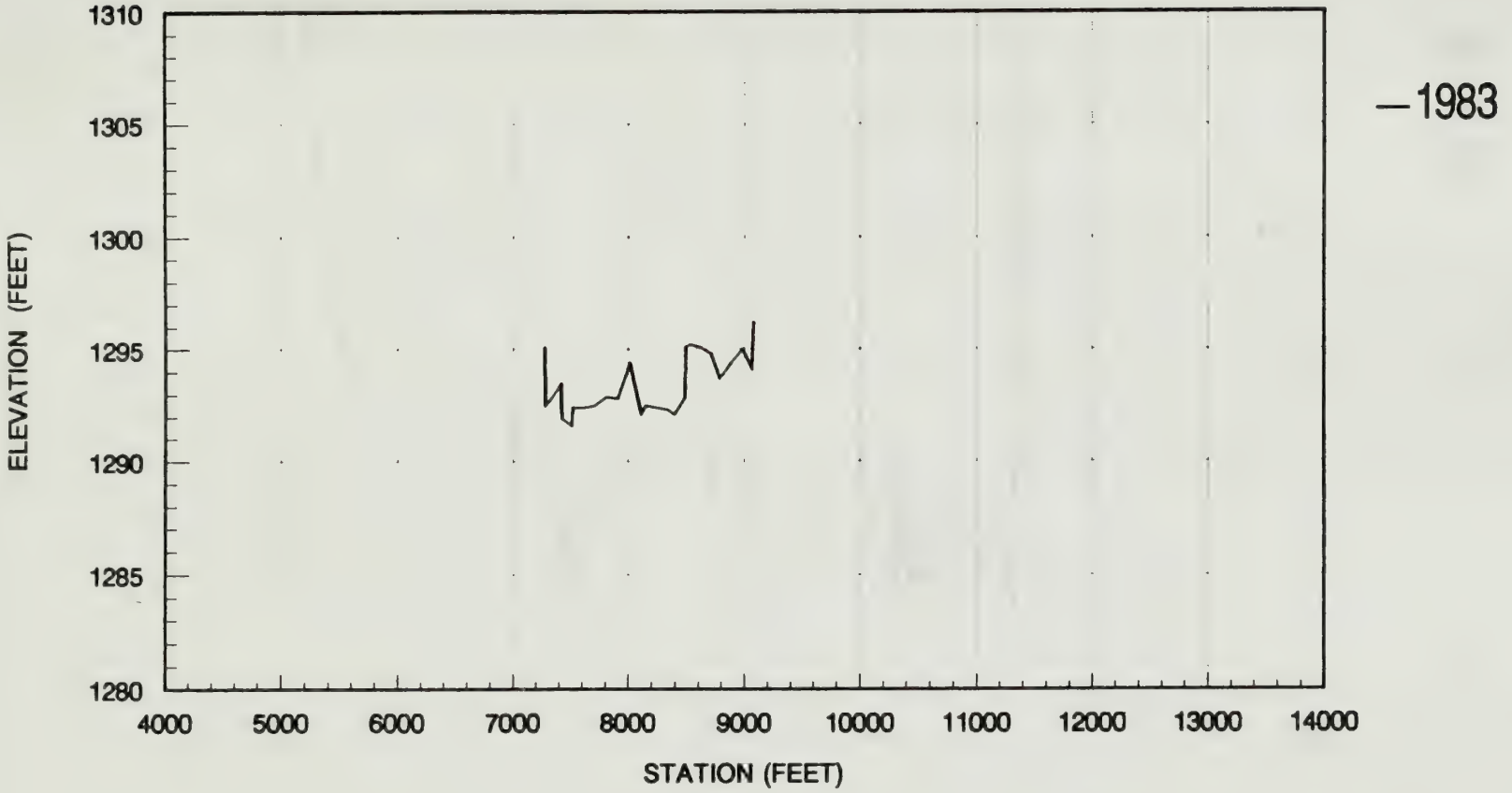
Plate III.31

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N11.6

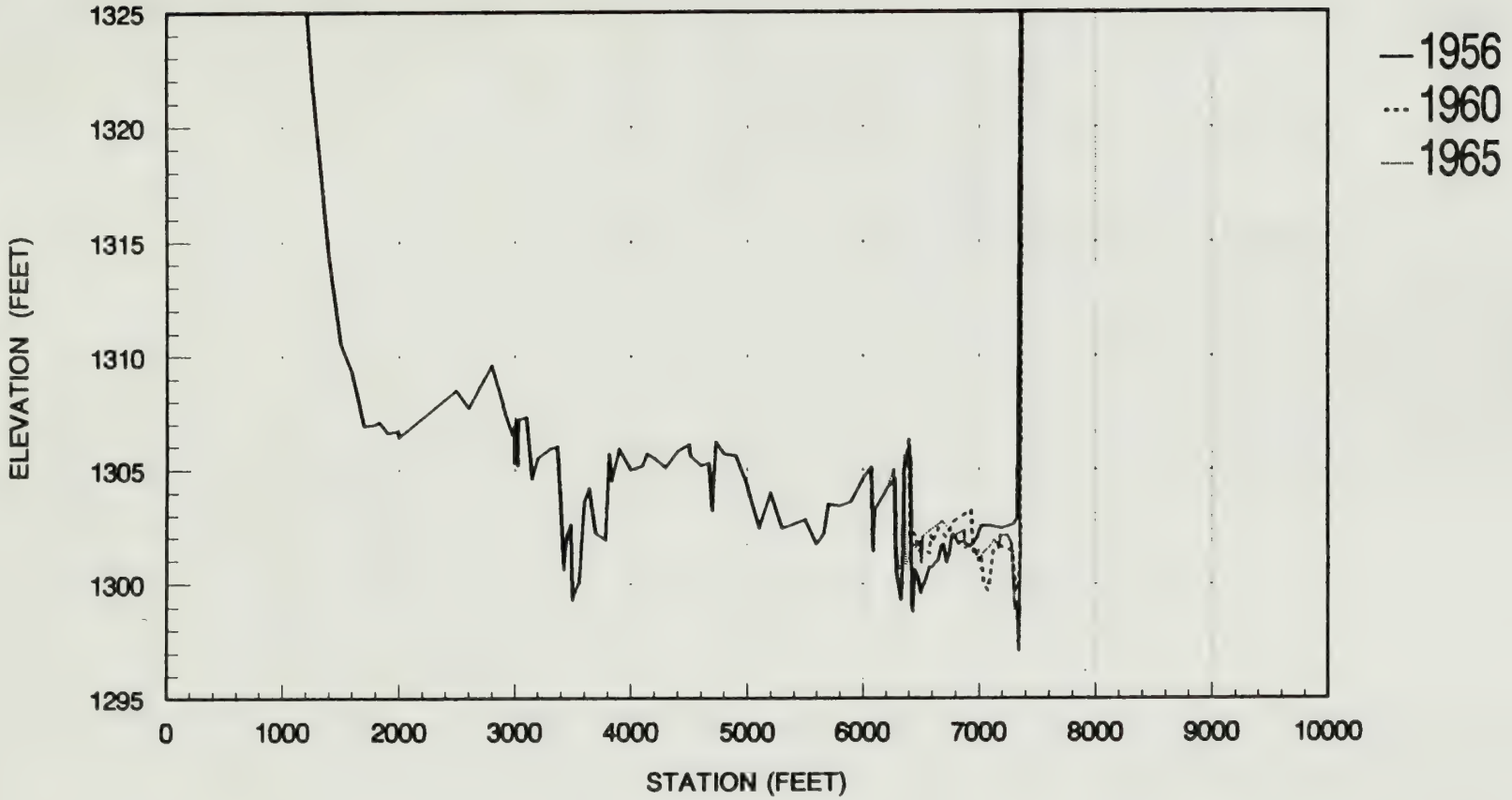


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N13.0

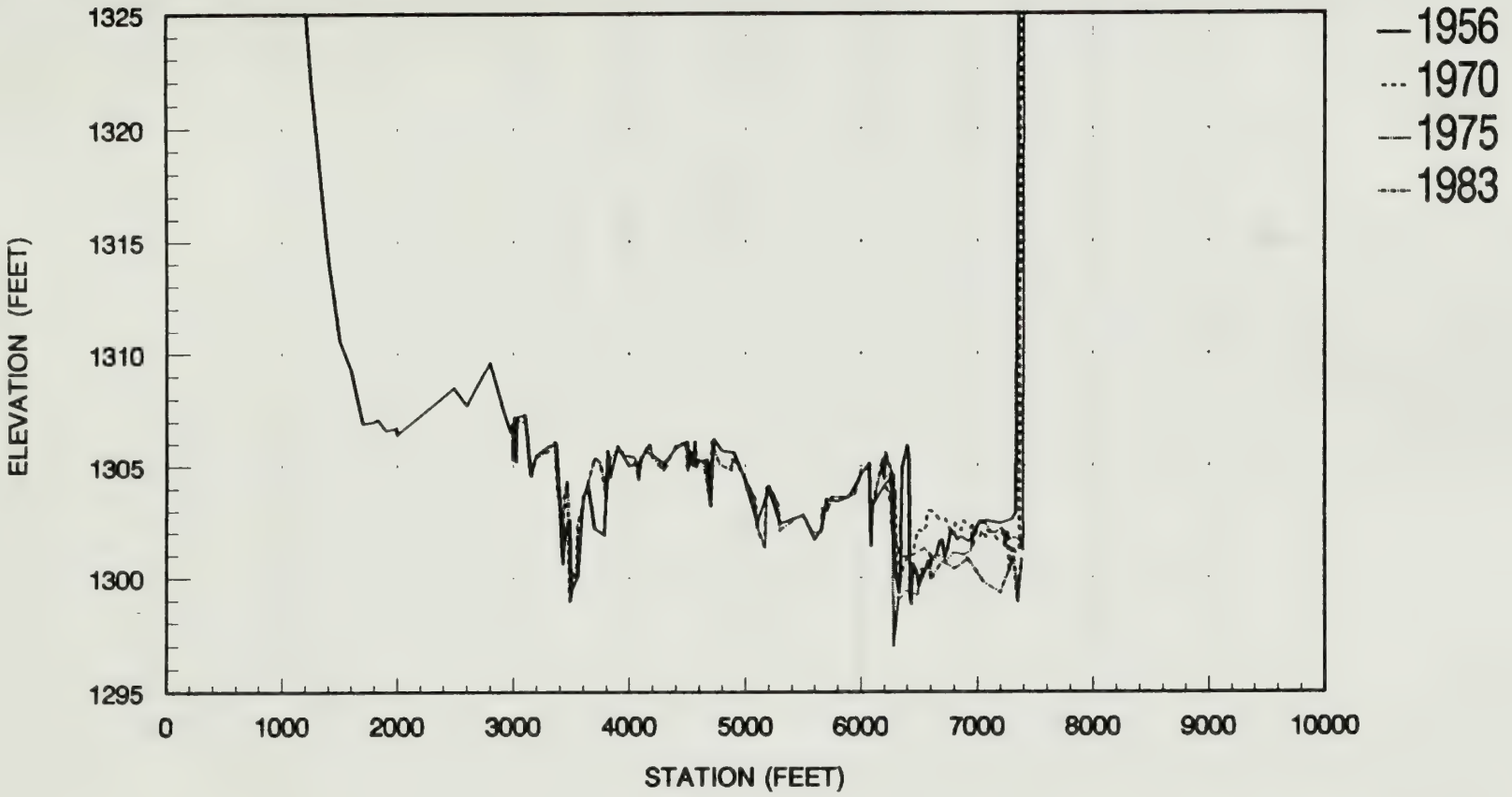


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N13.0

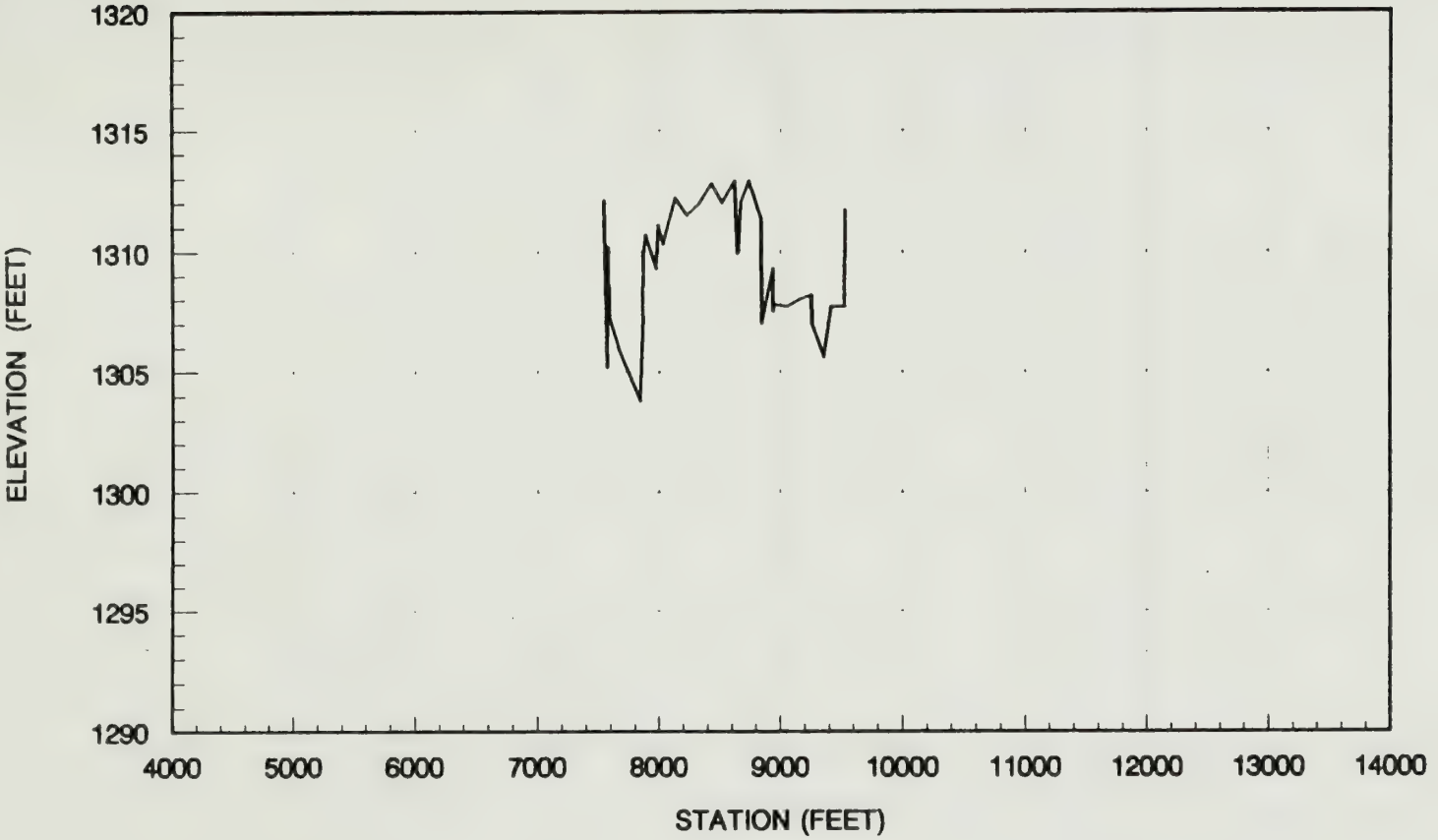


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N13.8



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE N14.5

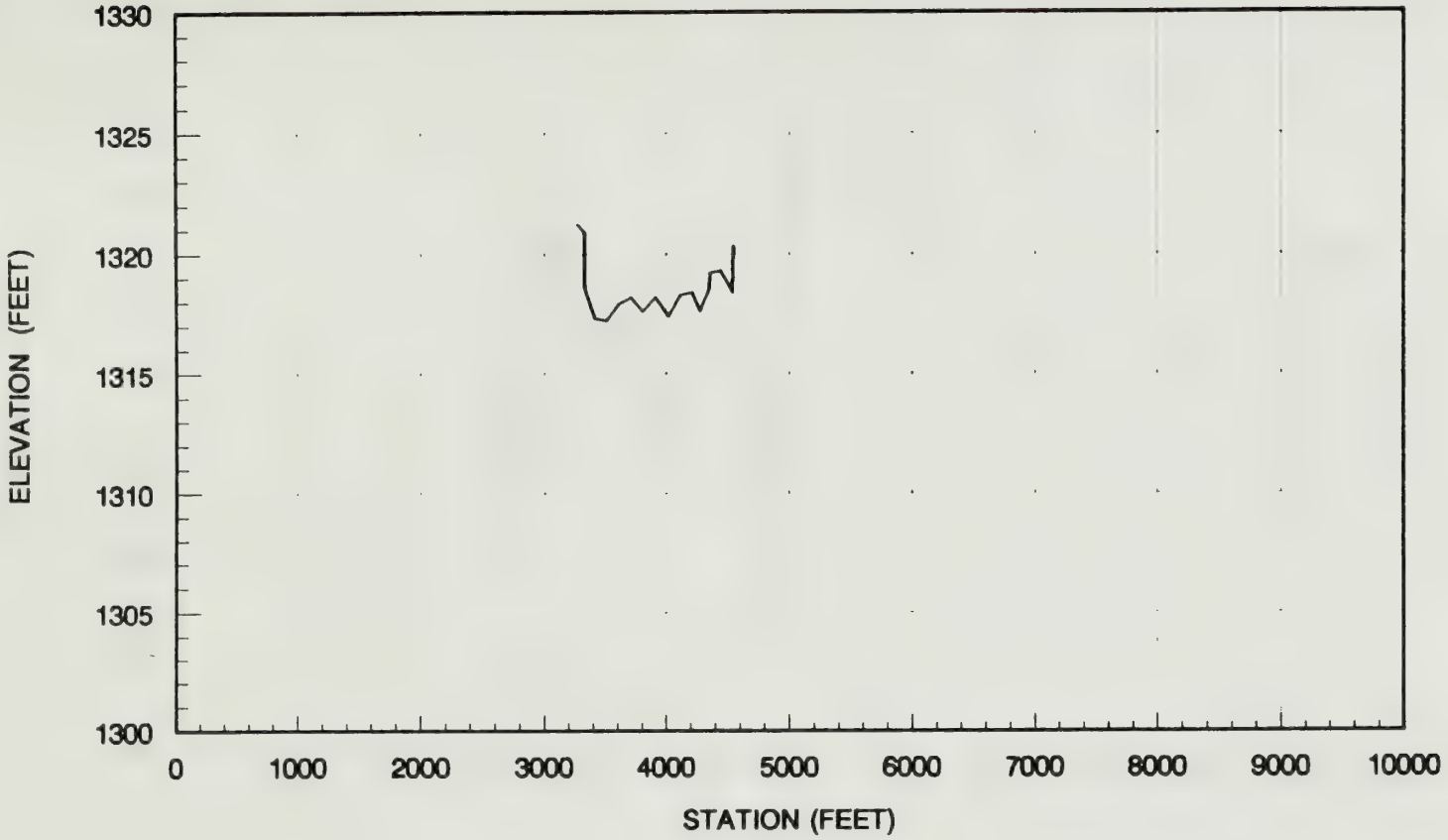


Plate III.36

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 881.4

(1960 RIVER MILE 840.0)

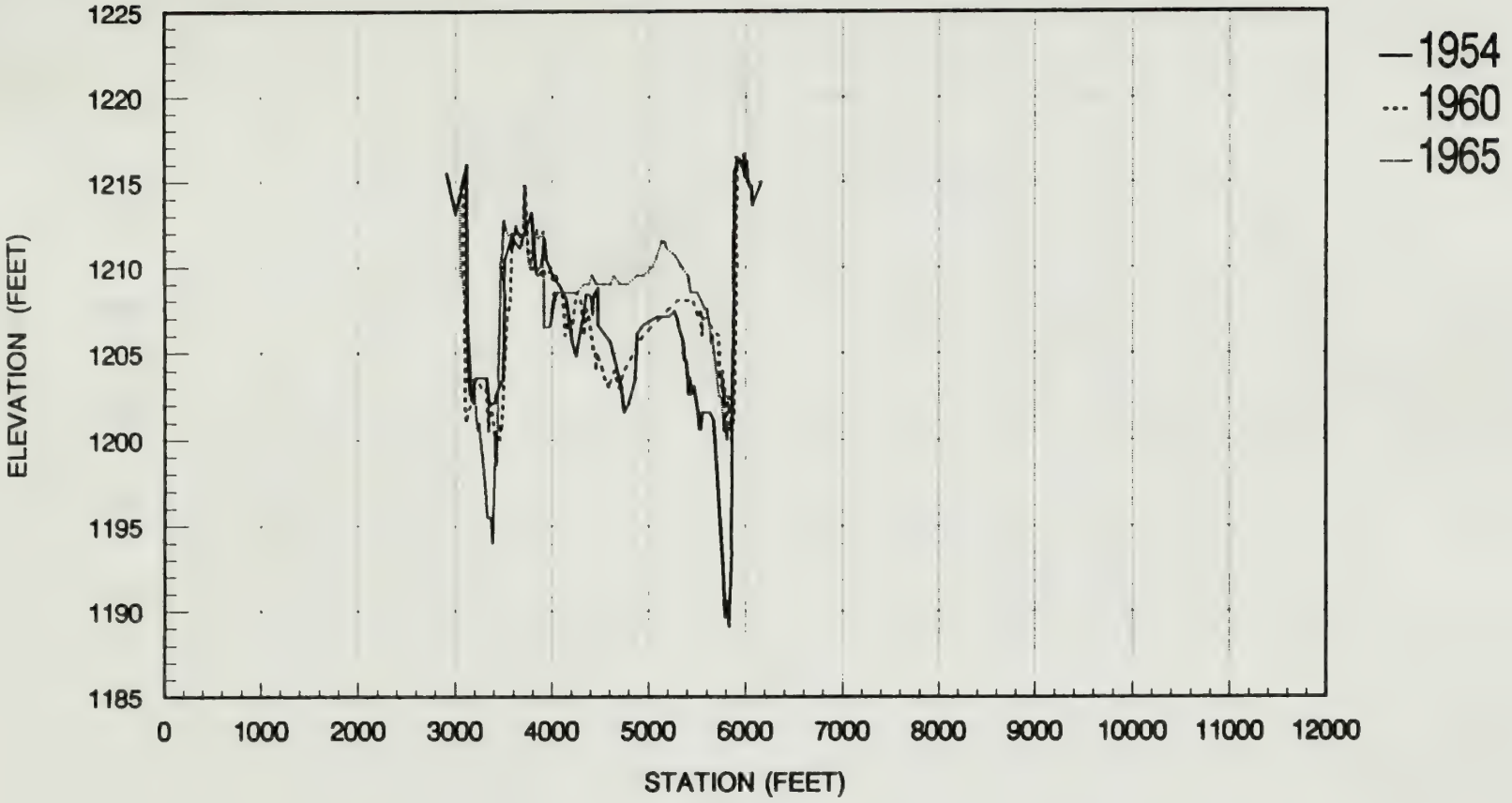


Plate III.37

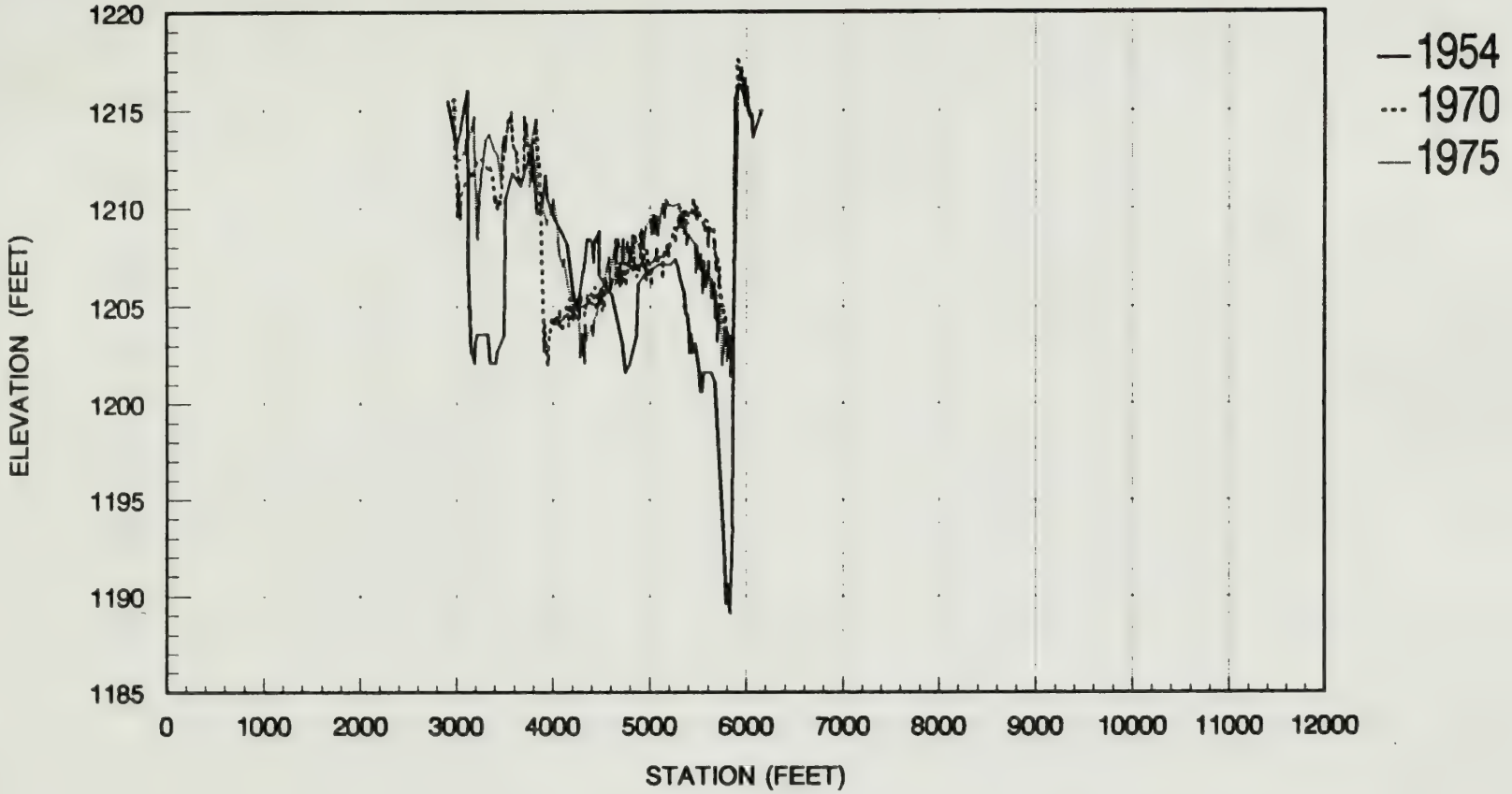
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 881.4

(1960 RIVER MILE 840.0)



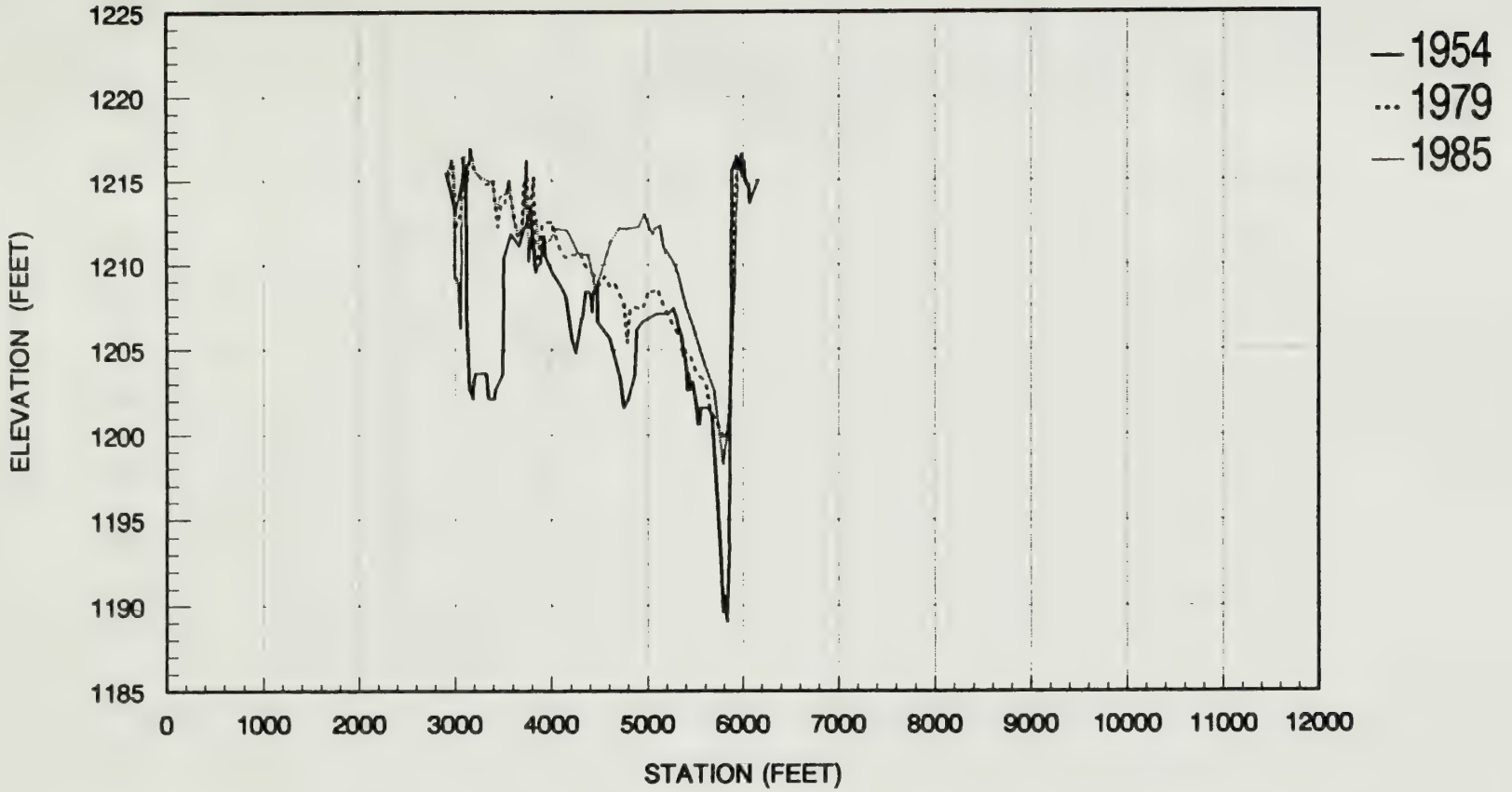
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 881.4

(1960 RIVER MILE 840.0)

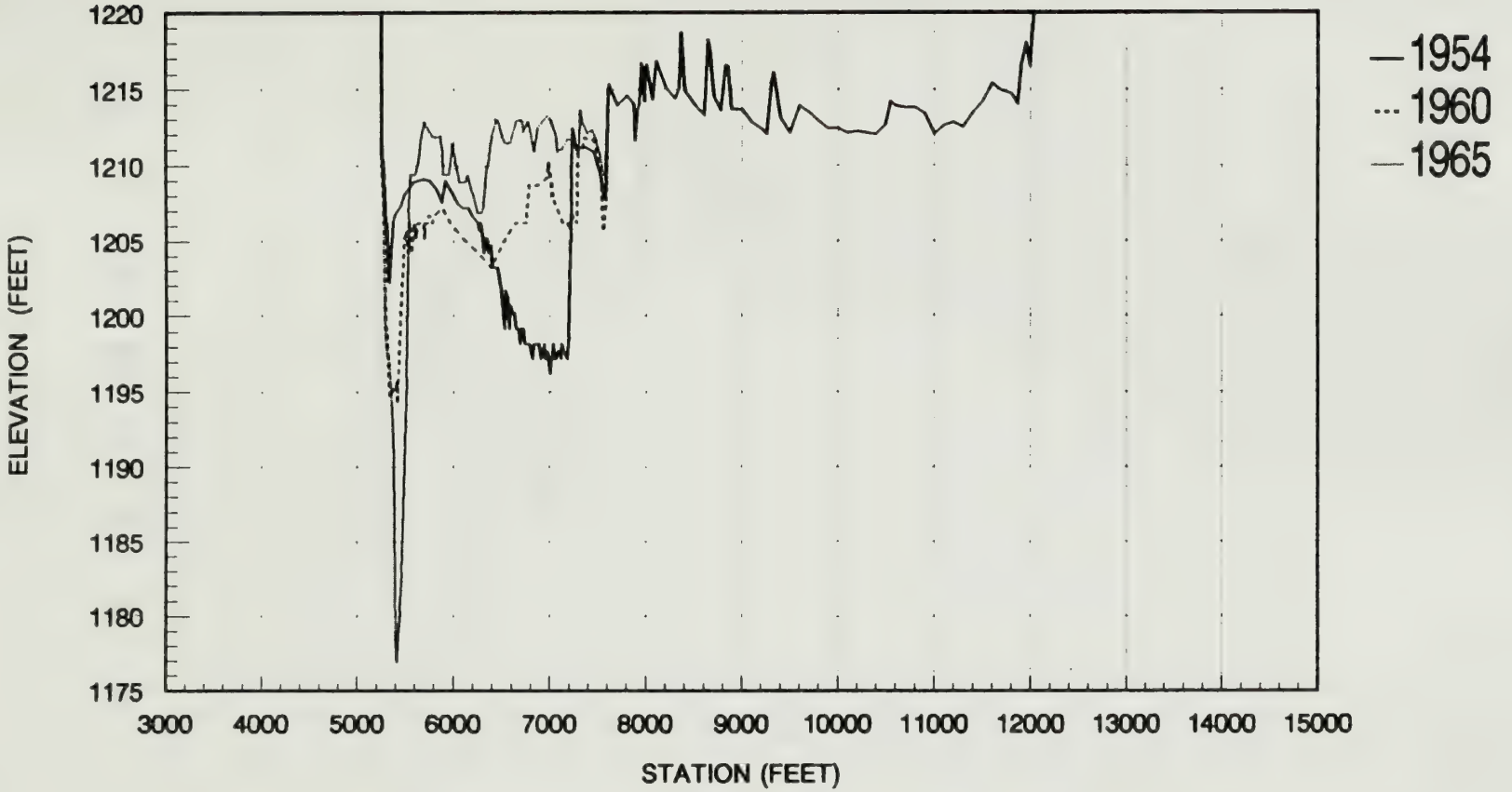


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 840.6)



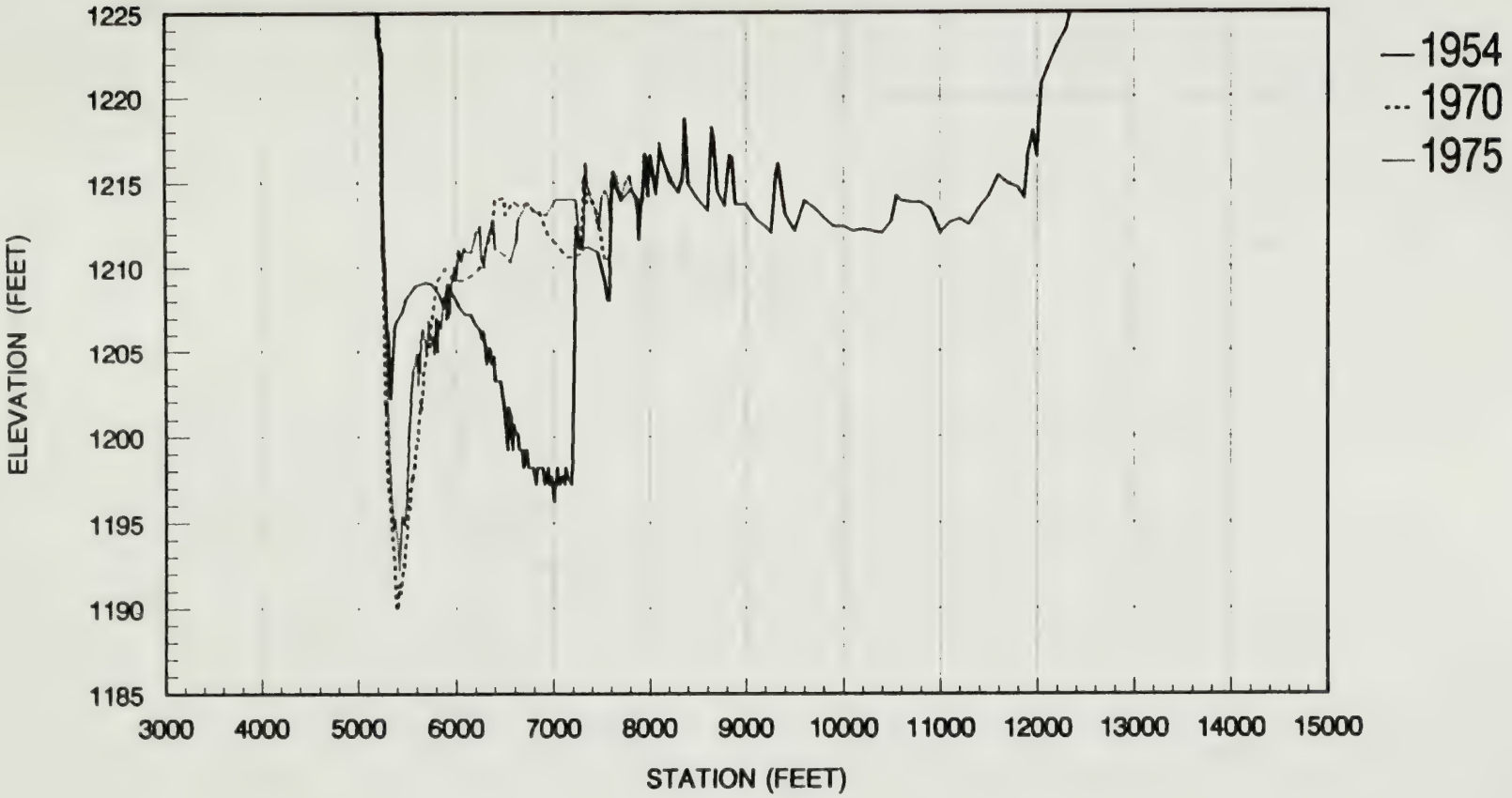
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 882.0

(1960 RIVER MILE 840.6)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER

CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 852.0

(1960 RIVER MILE 840.6)

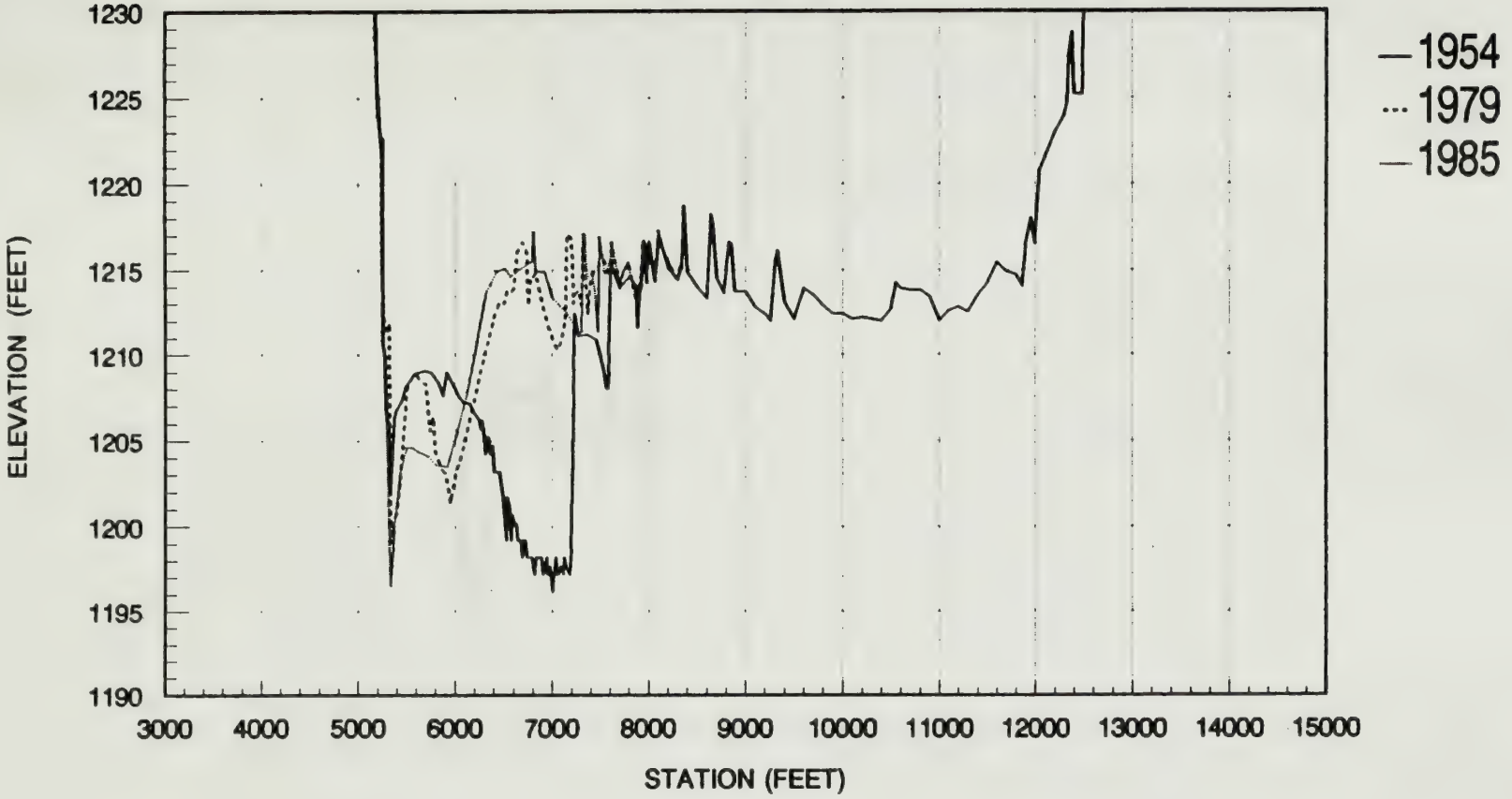


Plate III.42

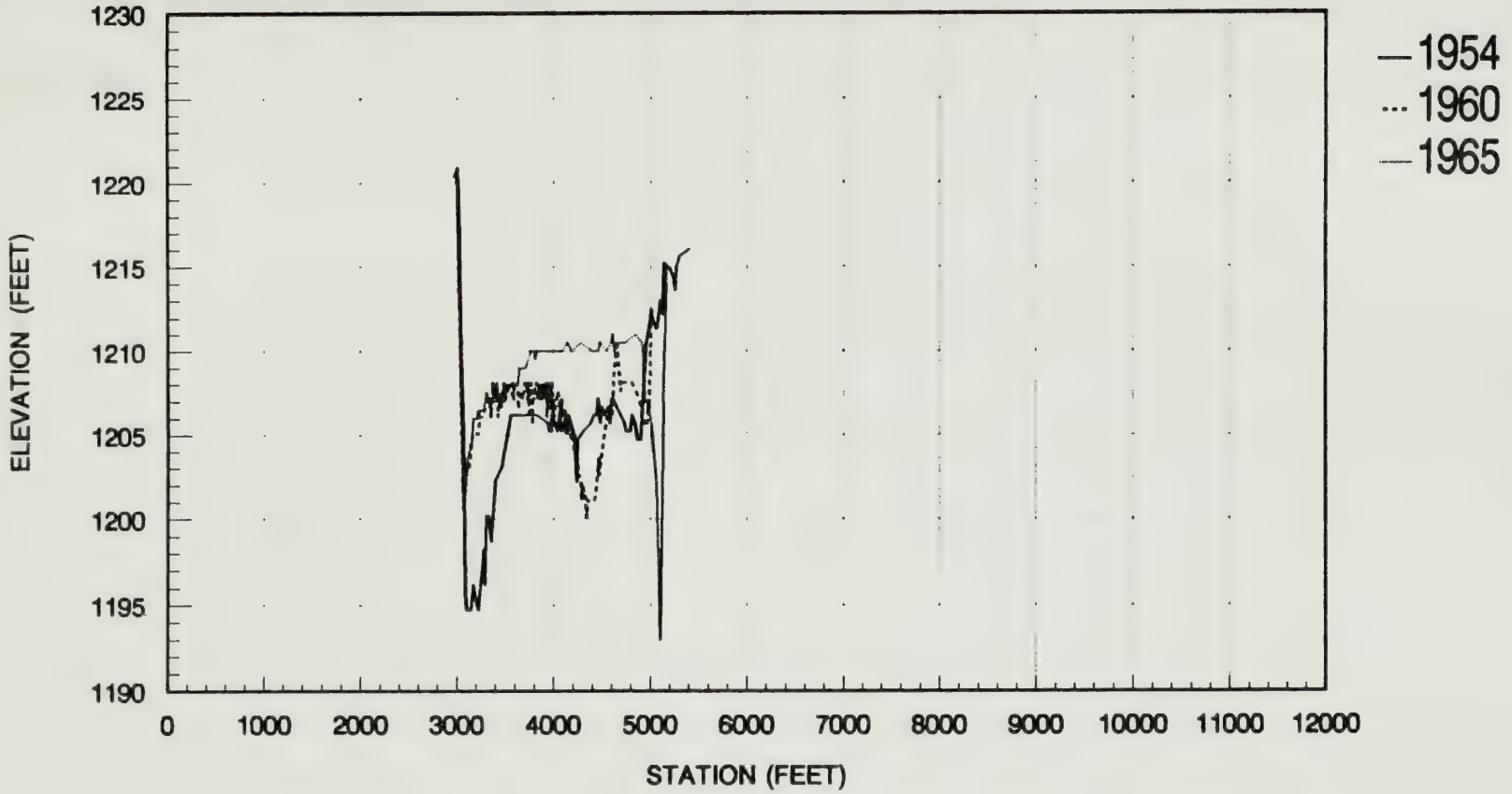
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 882.6

(1960 RIVER MILE 841.2)



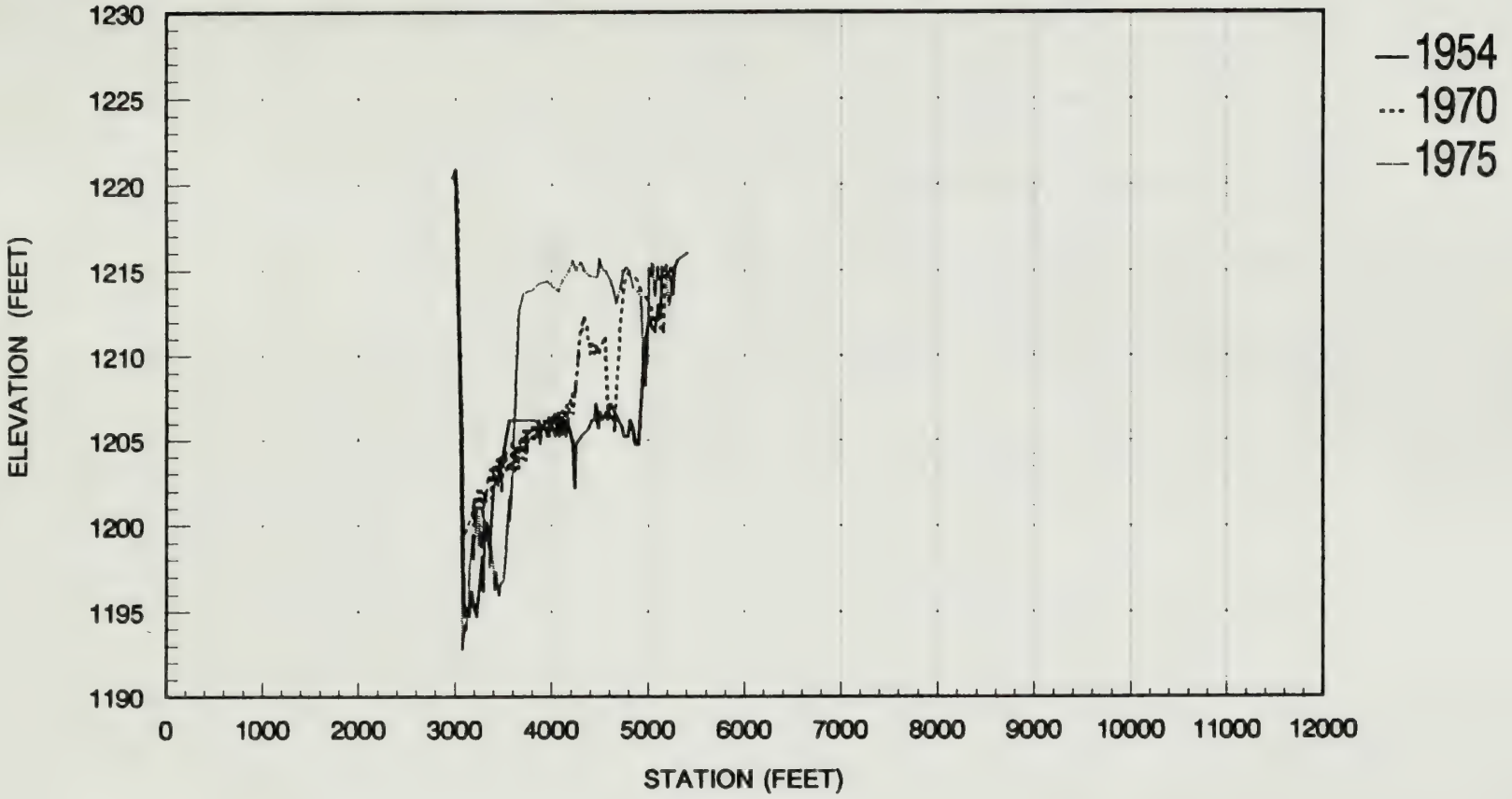
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

Plate III.43

(1960 RIVER MILE 841.2)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 841.2)

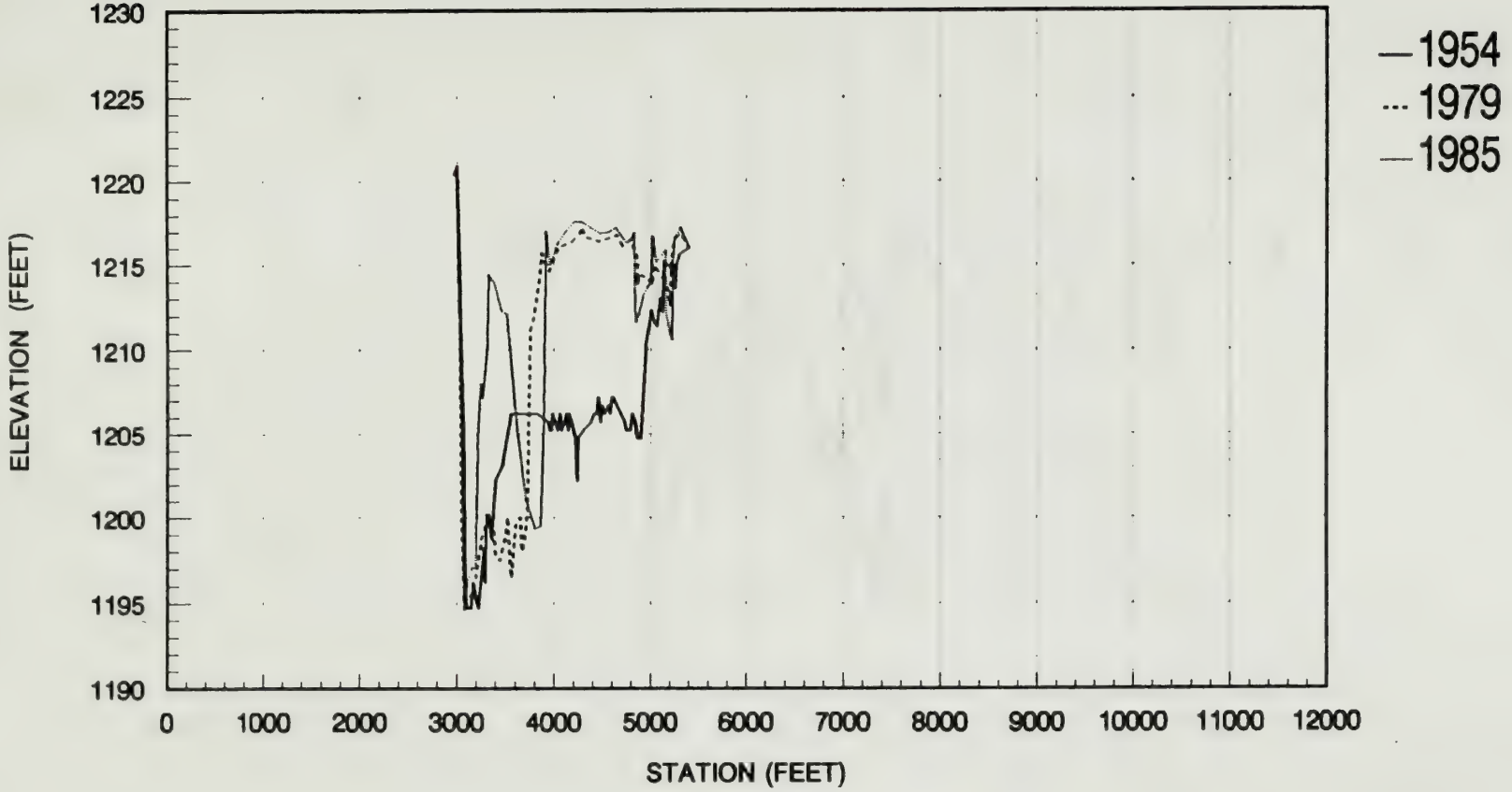


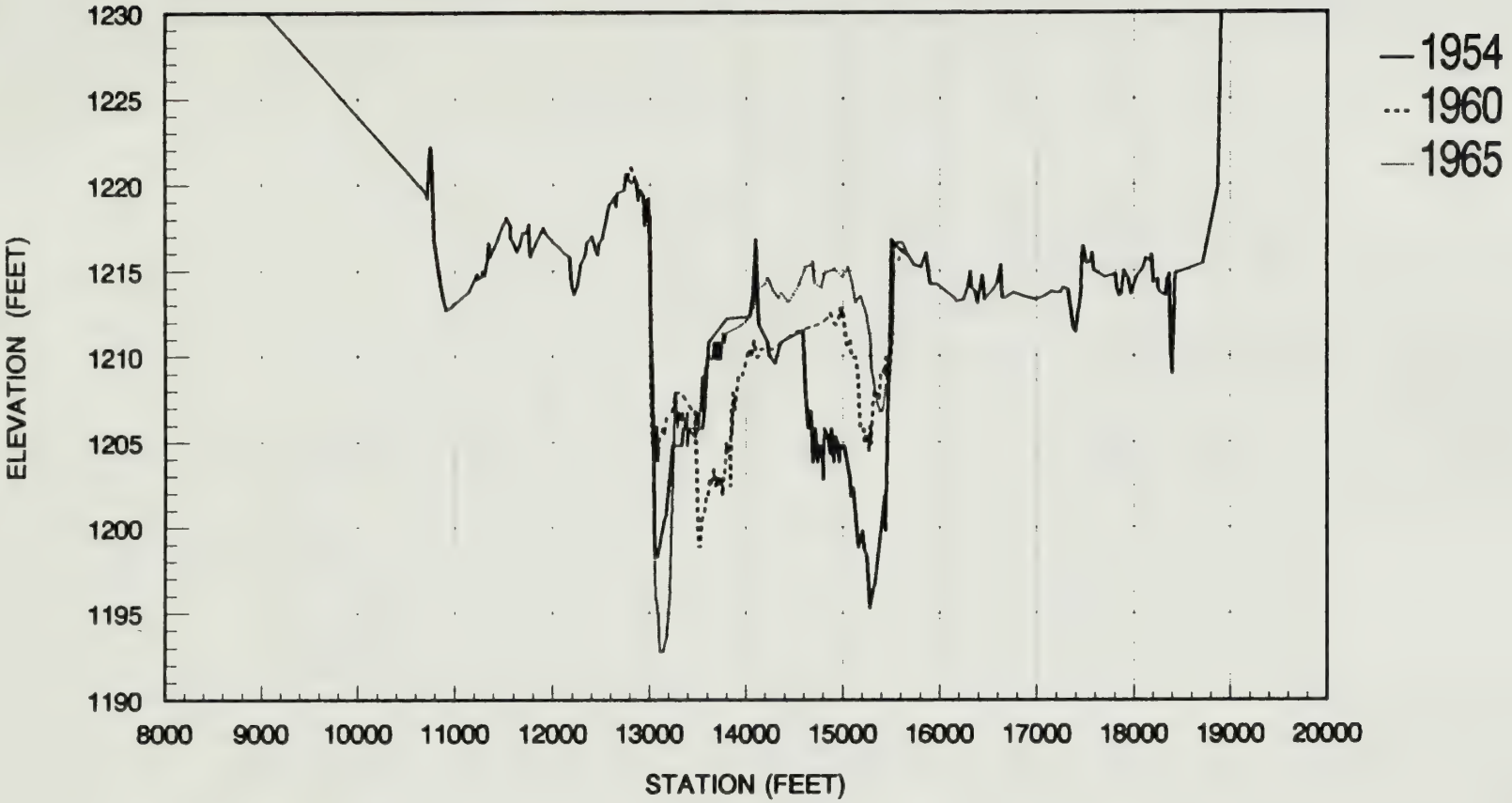
Plate III.45

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 841.9)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 838.8

(1960 RIVER MILE 841.9)

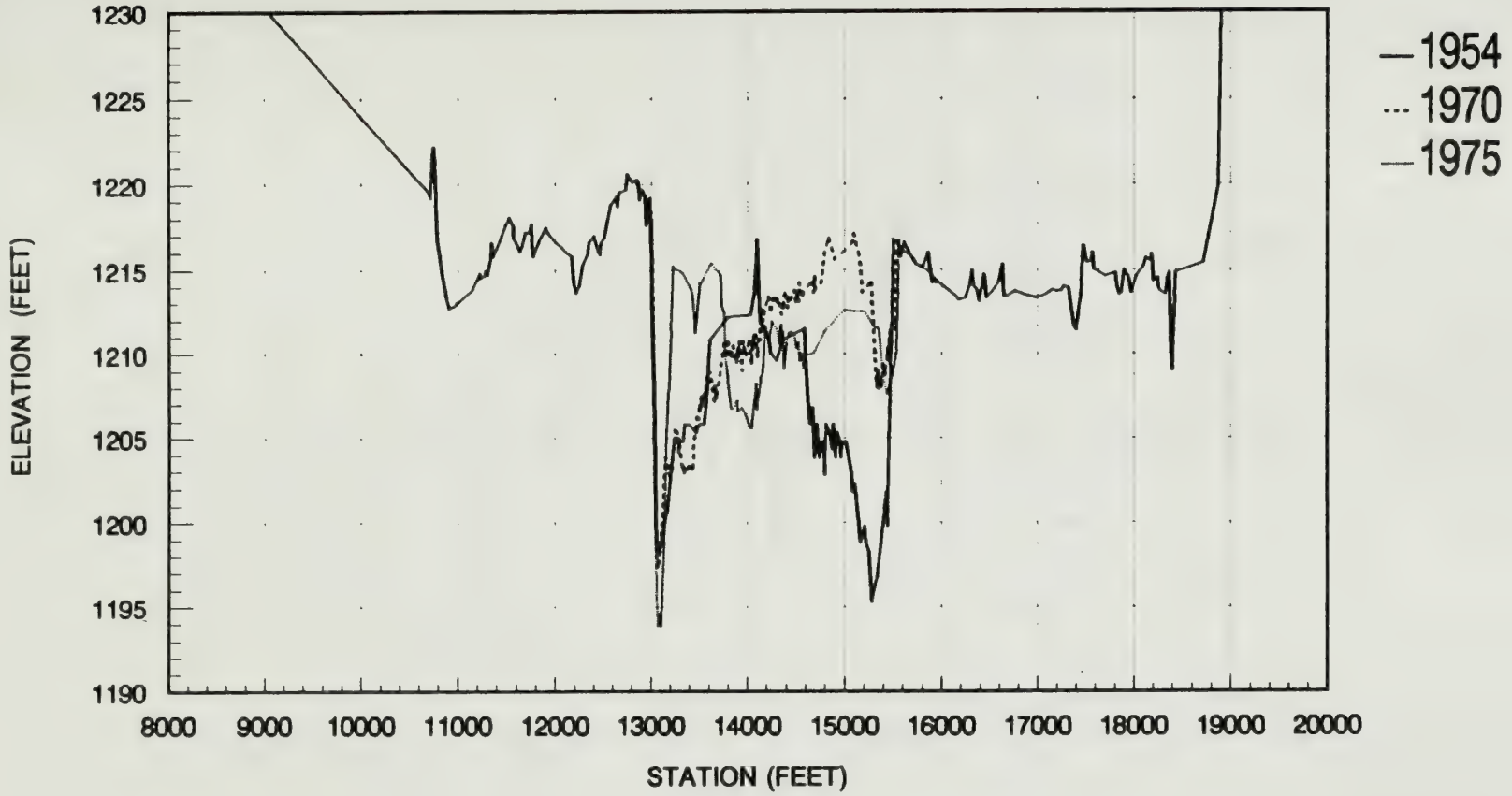


Plate III.47

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 841.9)

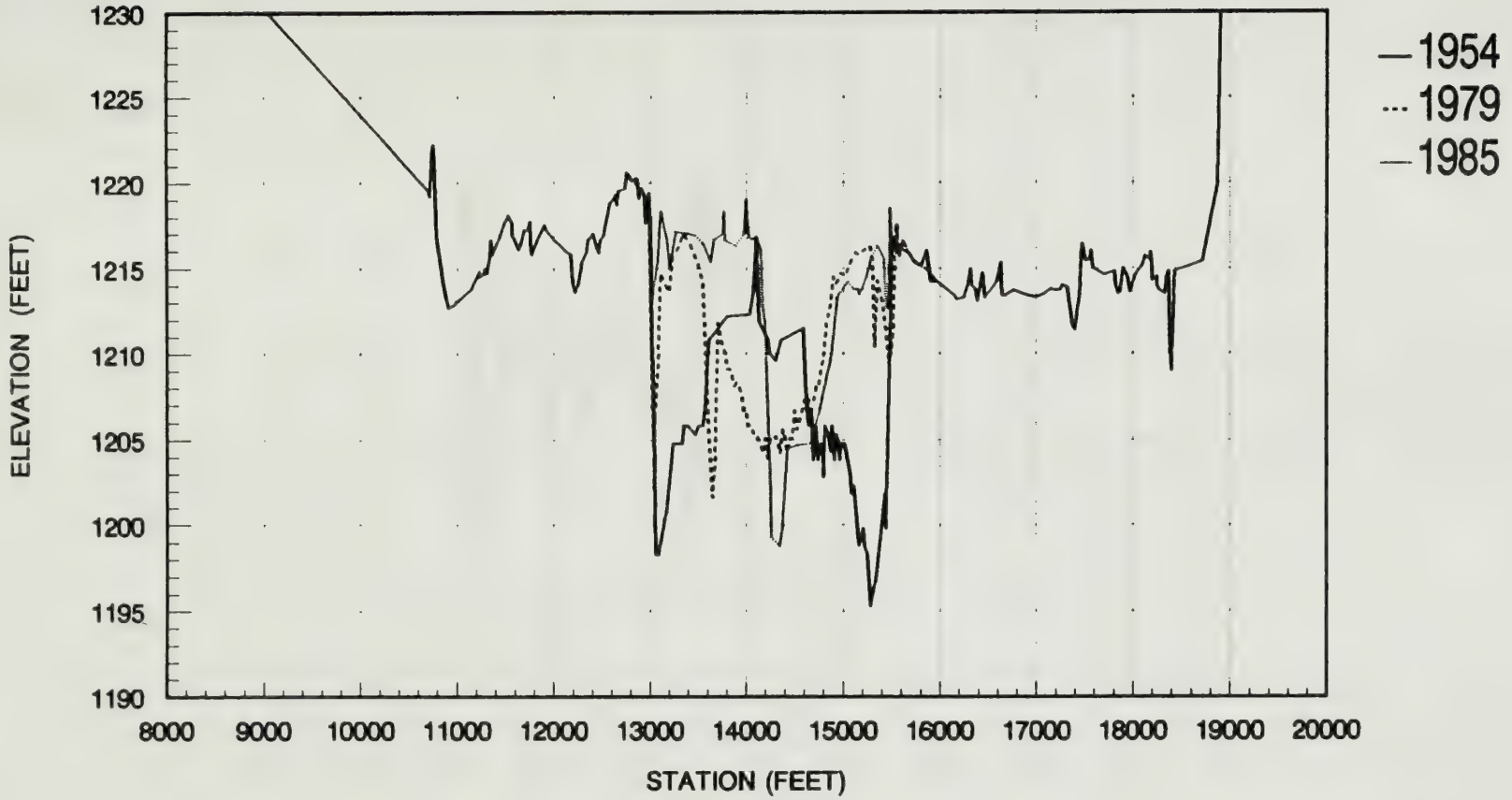


Plate III.48

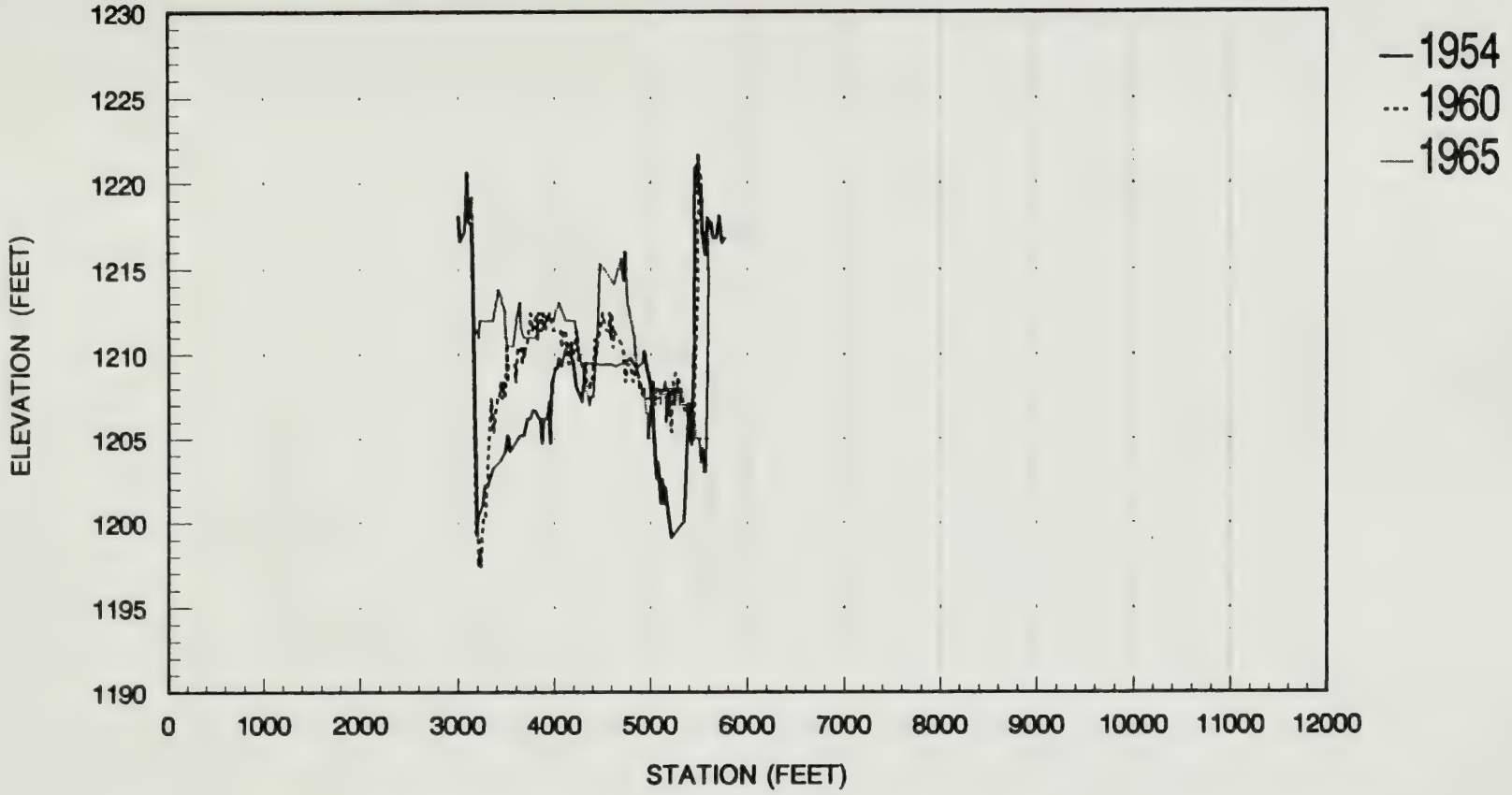
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 853.9

(1960 RIVER MILE 842.4)

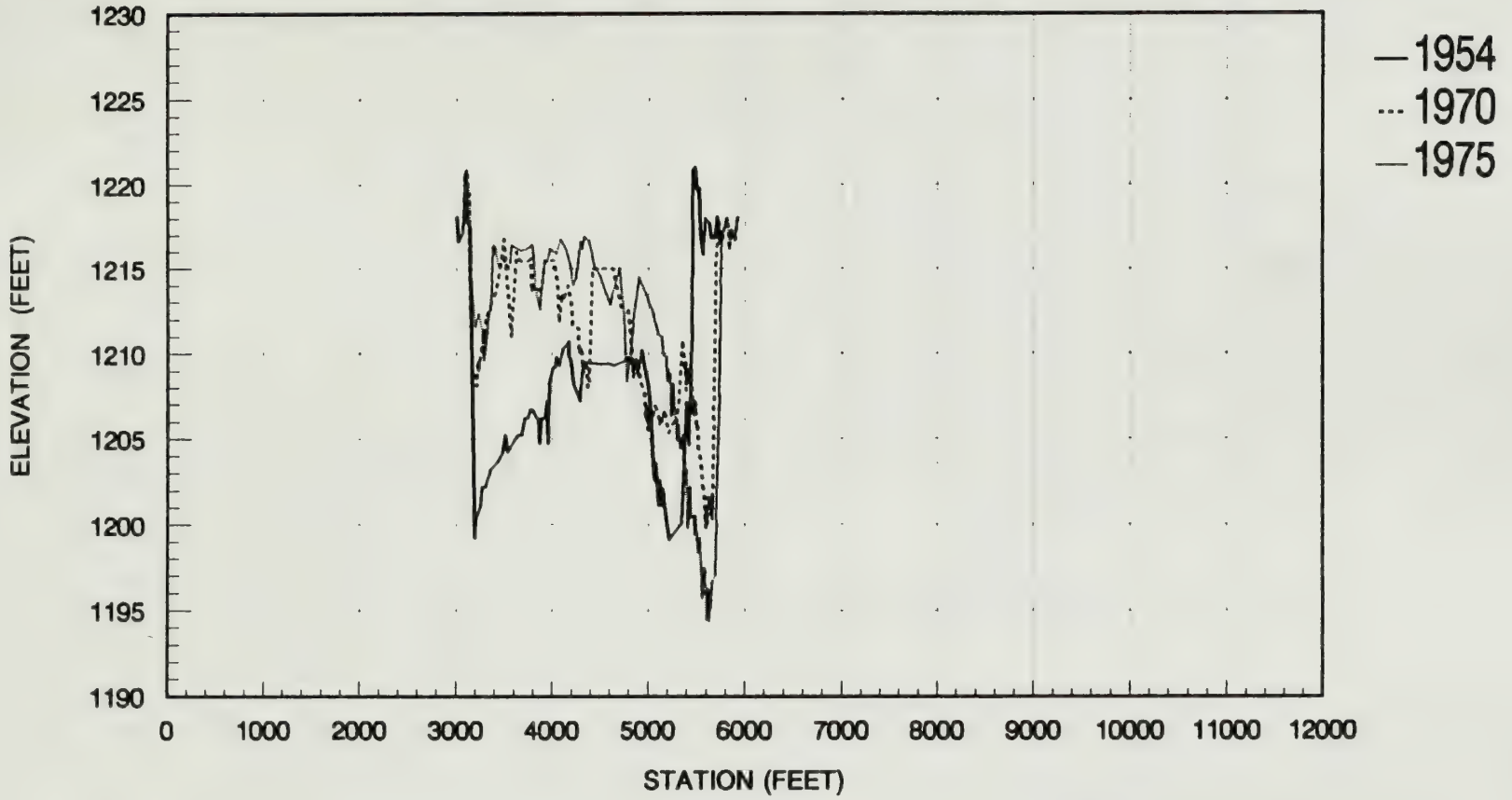


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 842.4)

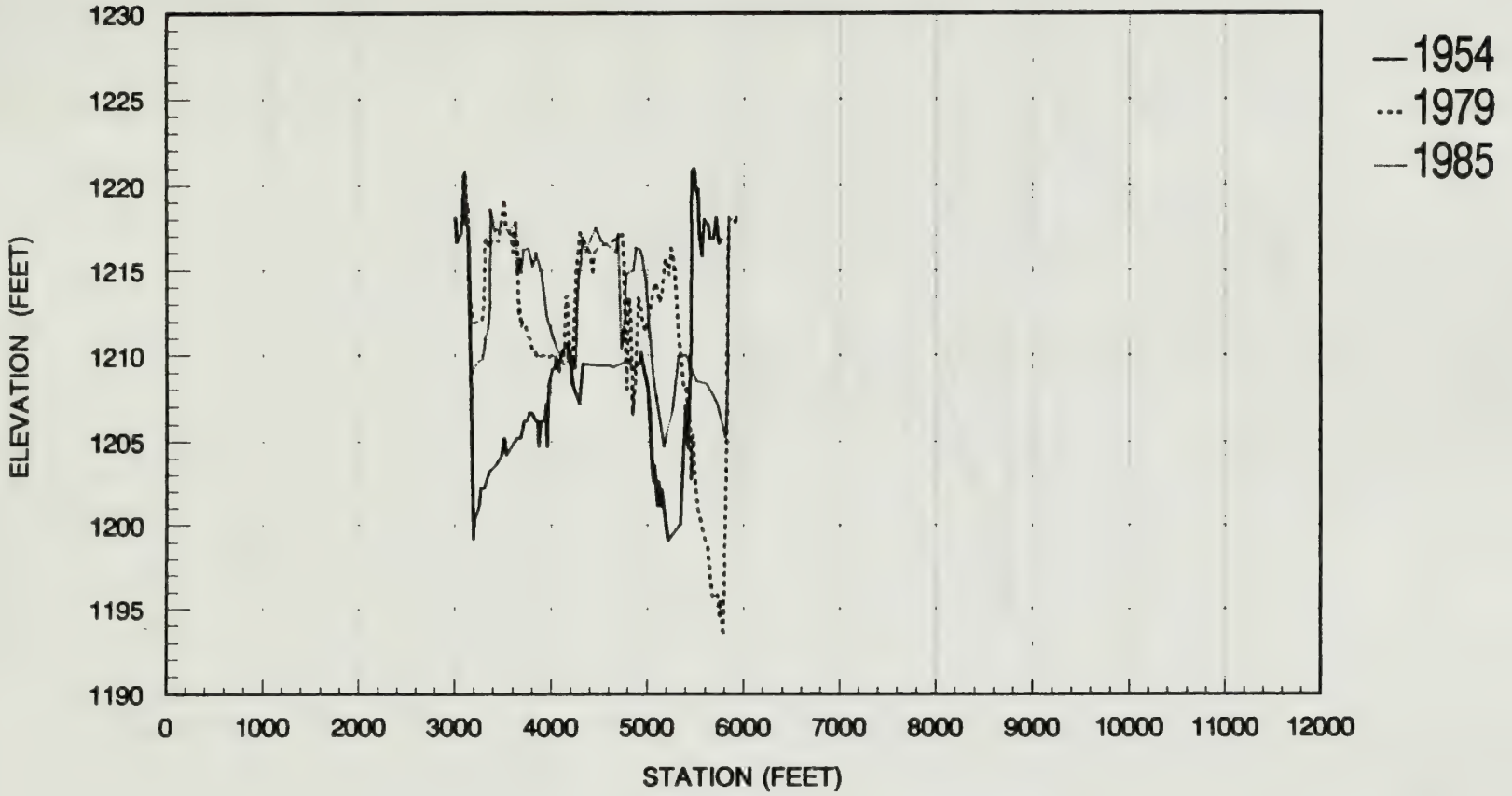


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 842.4)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 842.9)

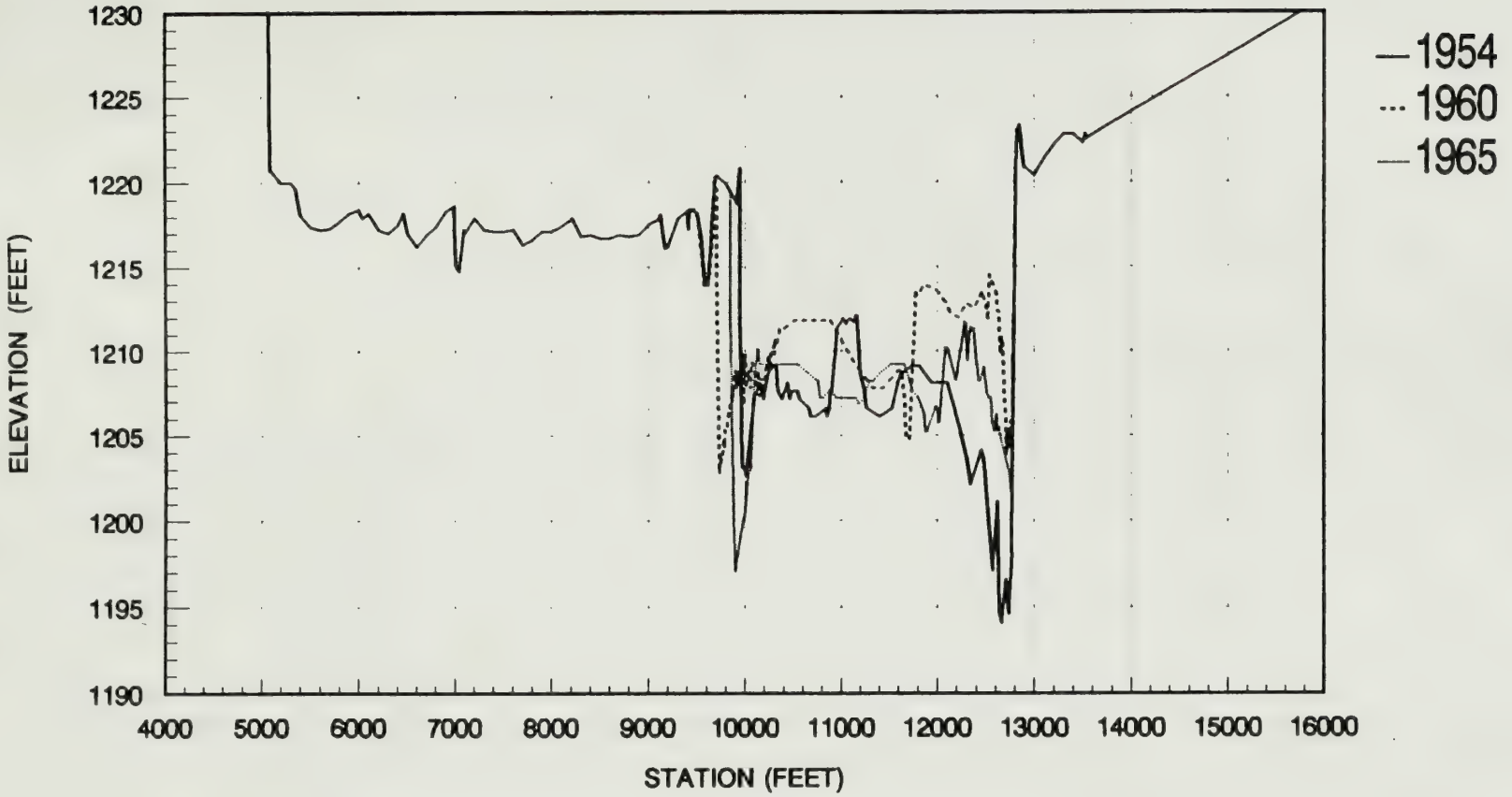


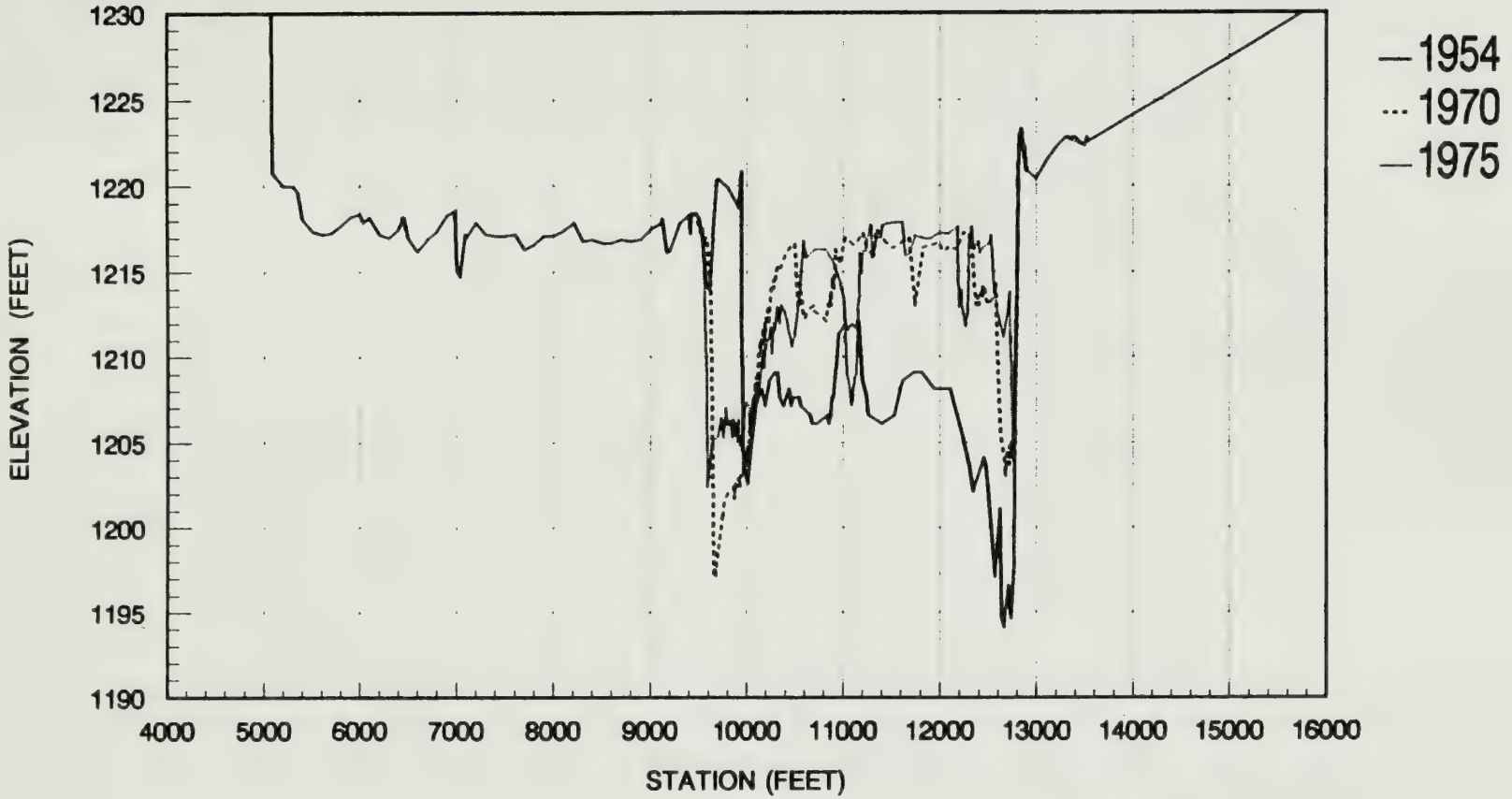
Plate III.52

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 842.9)

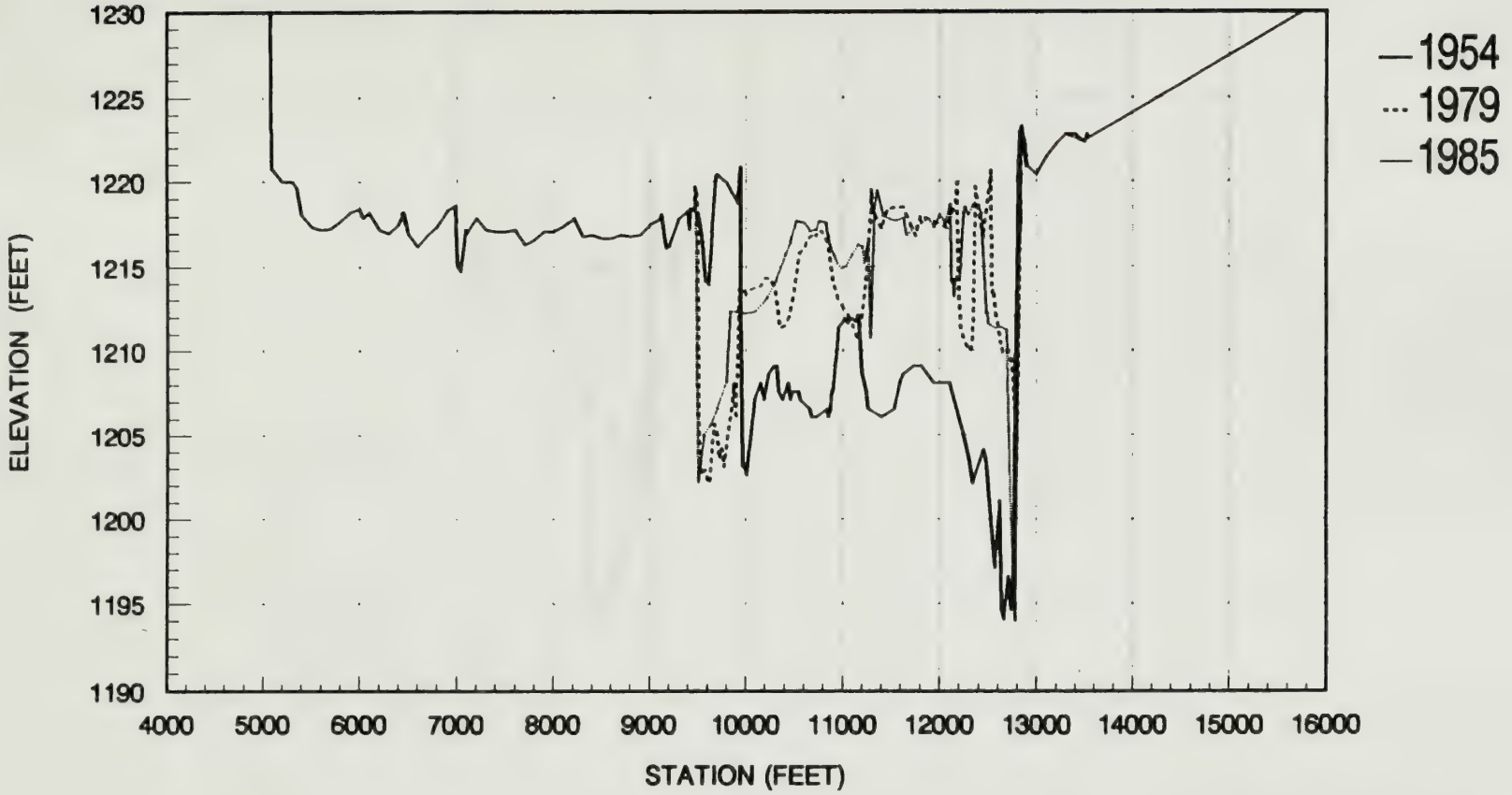


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 842.9)



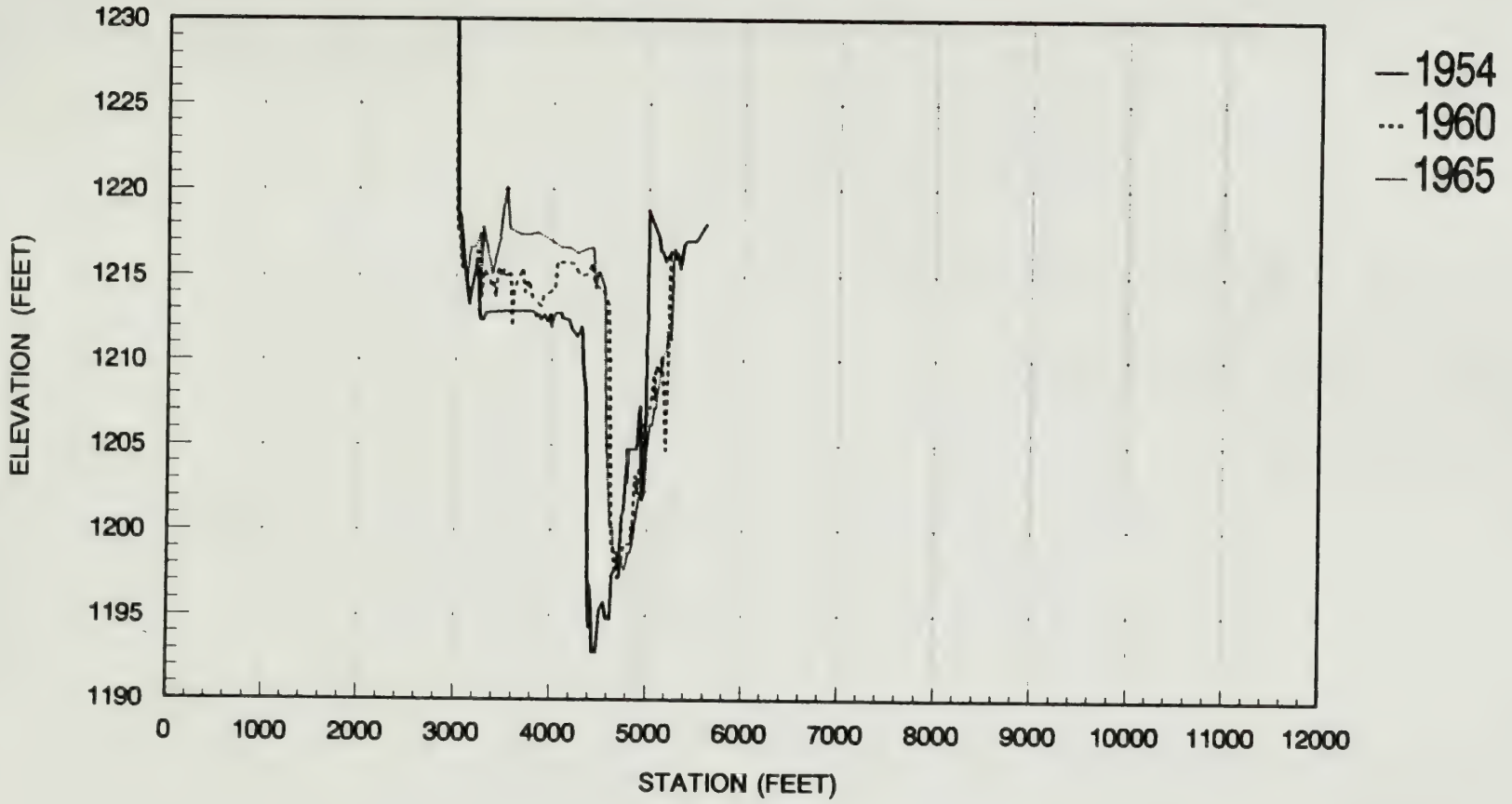
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 885.1

(1960 RIVER MILE 843.6)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 885.1

(1960 RIVER MILE 843.6)

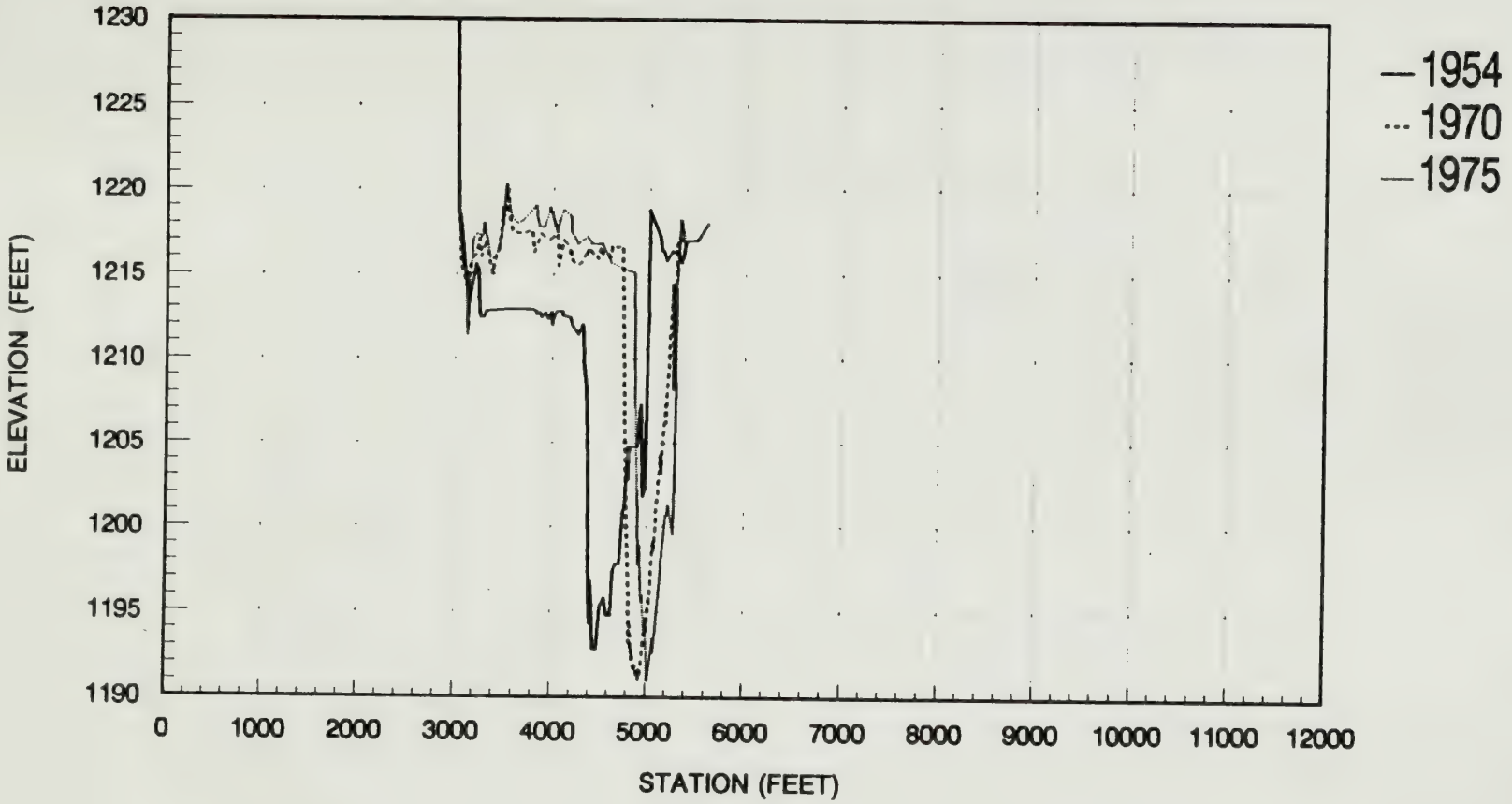


Plate III.56

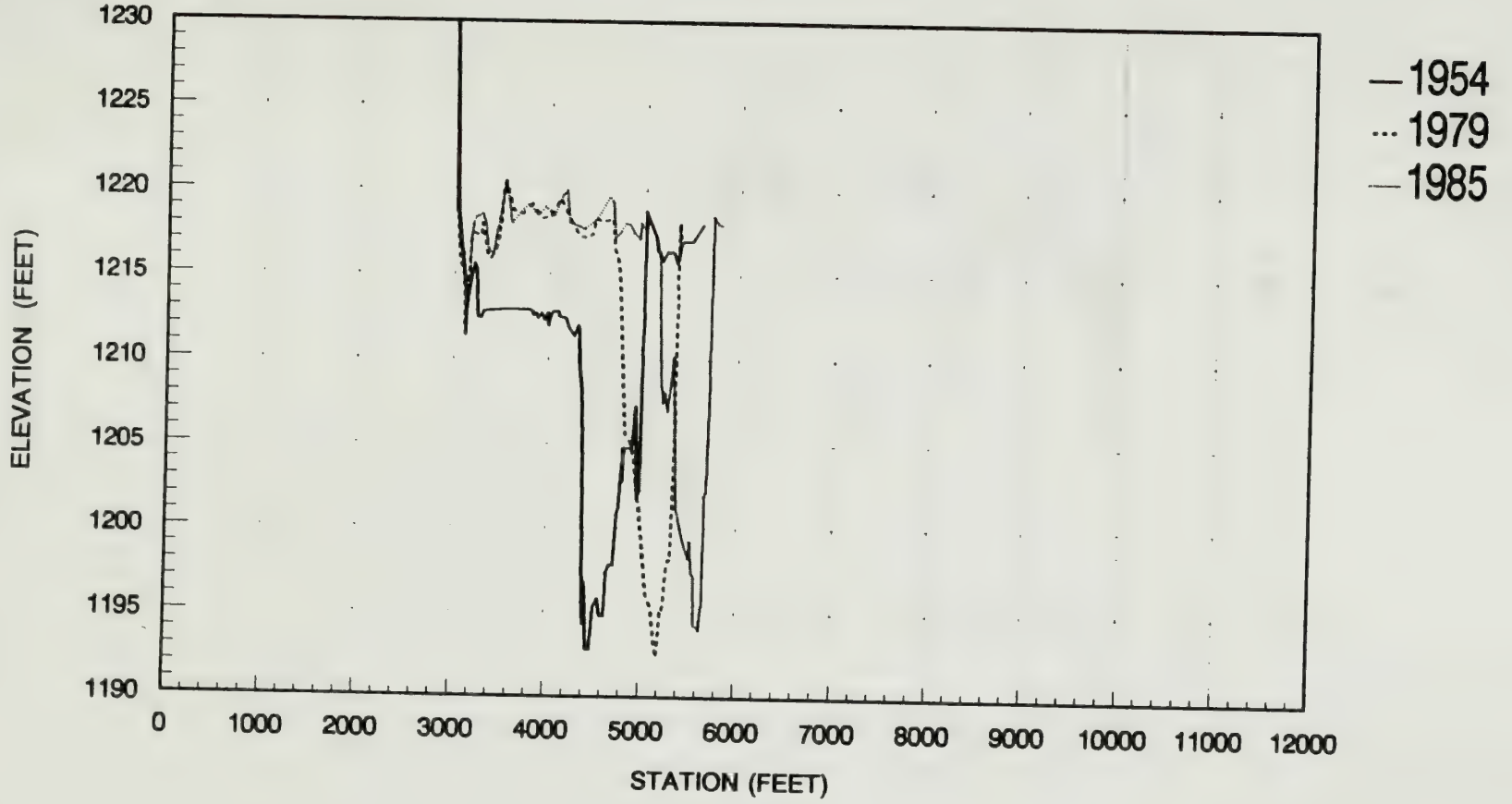
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 885.1

(1960 RIVER MILE 843.6)

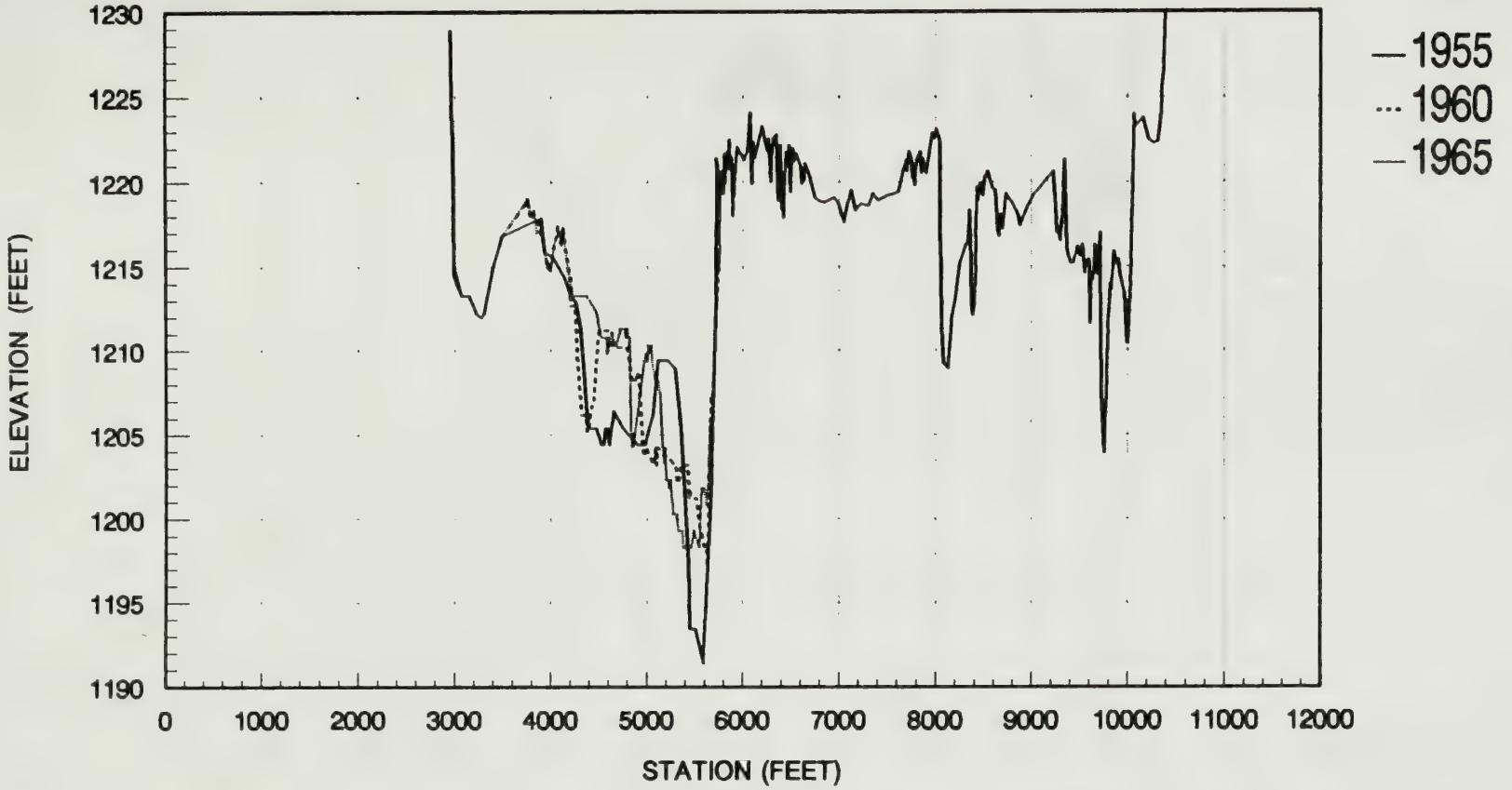


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

(1960 RIVER MILE 844.1)



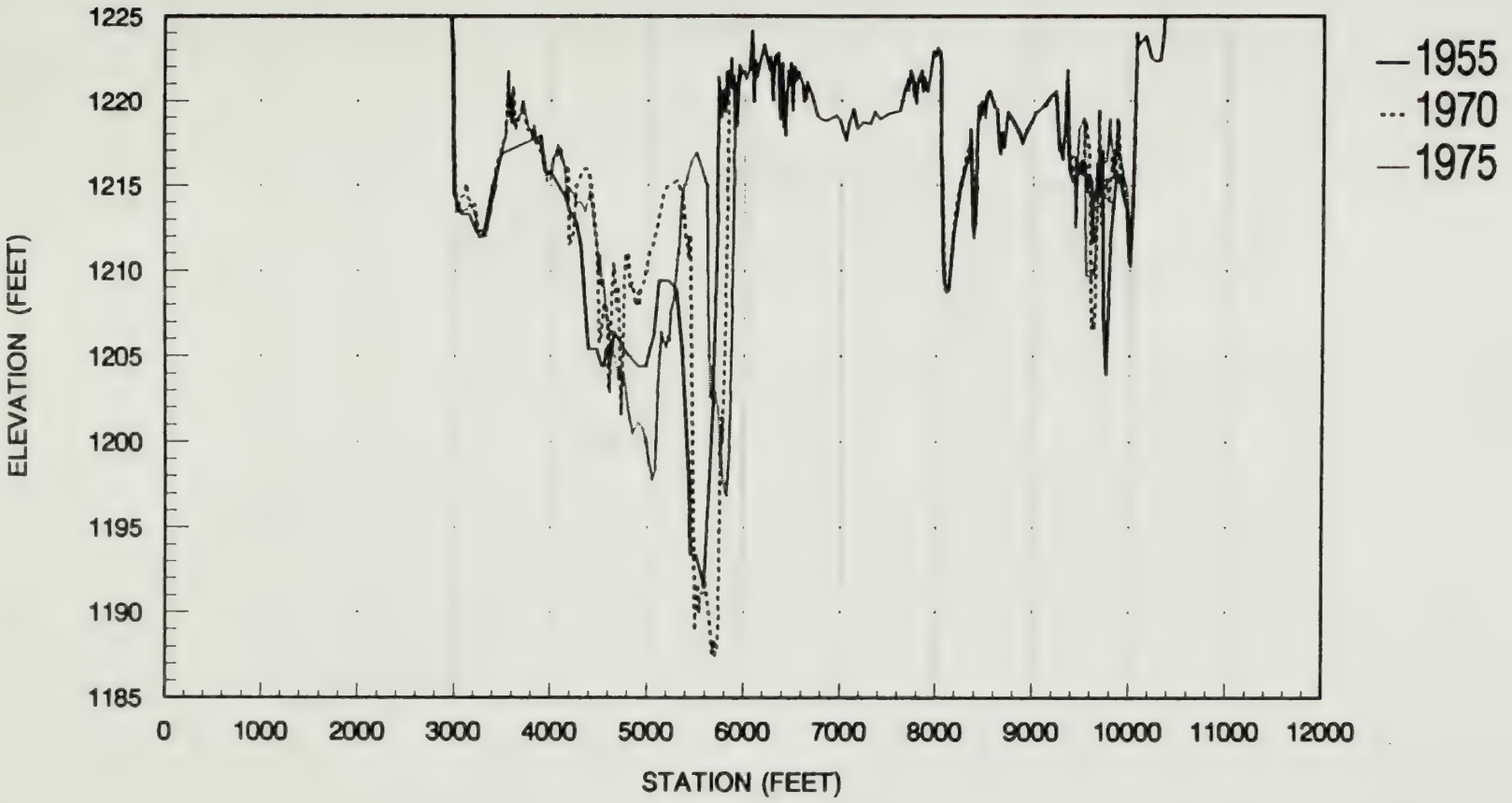
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 885.6

(1960 RIVER MILE 844.1)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 885.6

(1960 RIVER MILE 844.1)

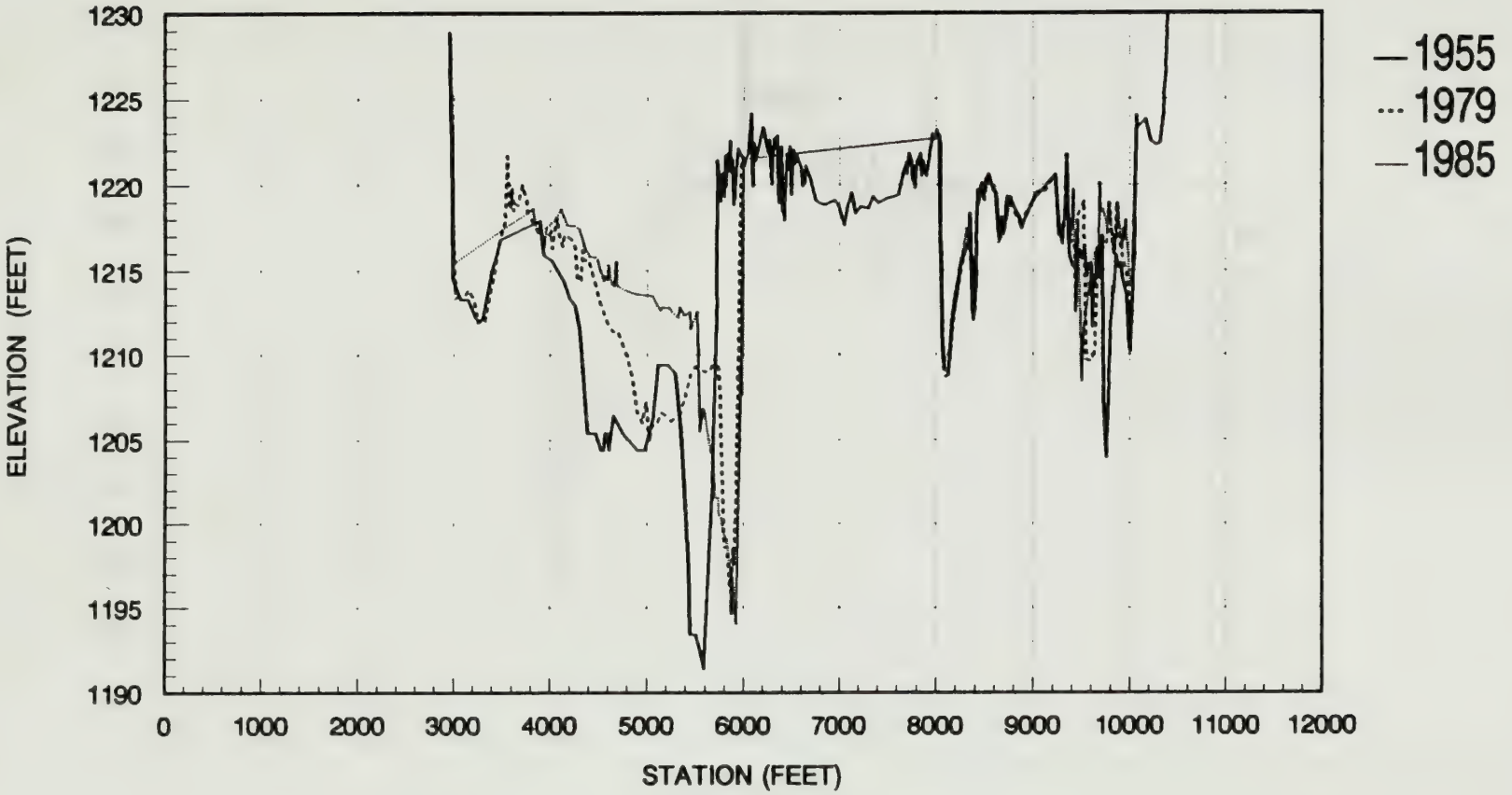


Plate III.60

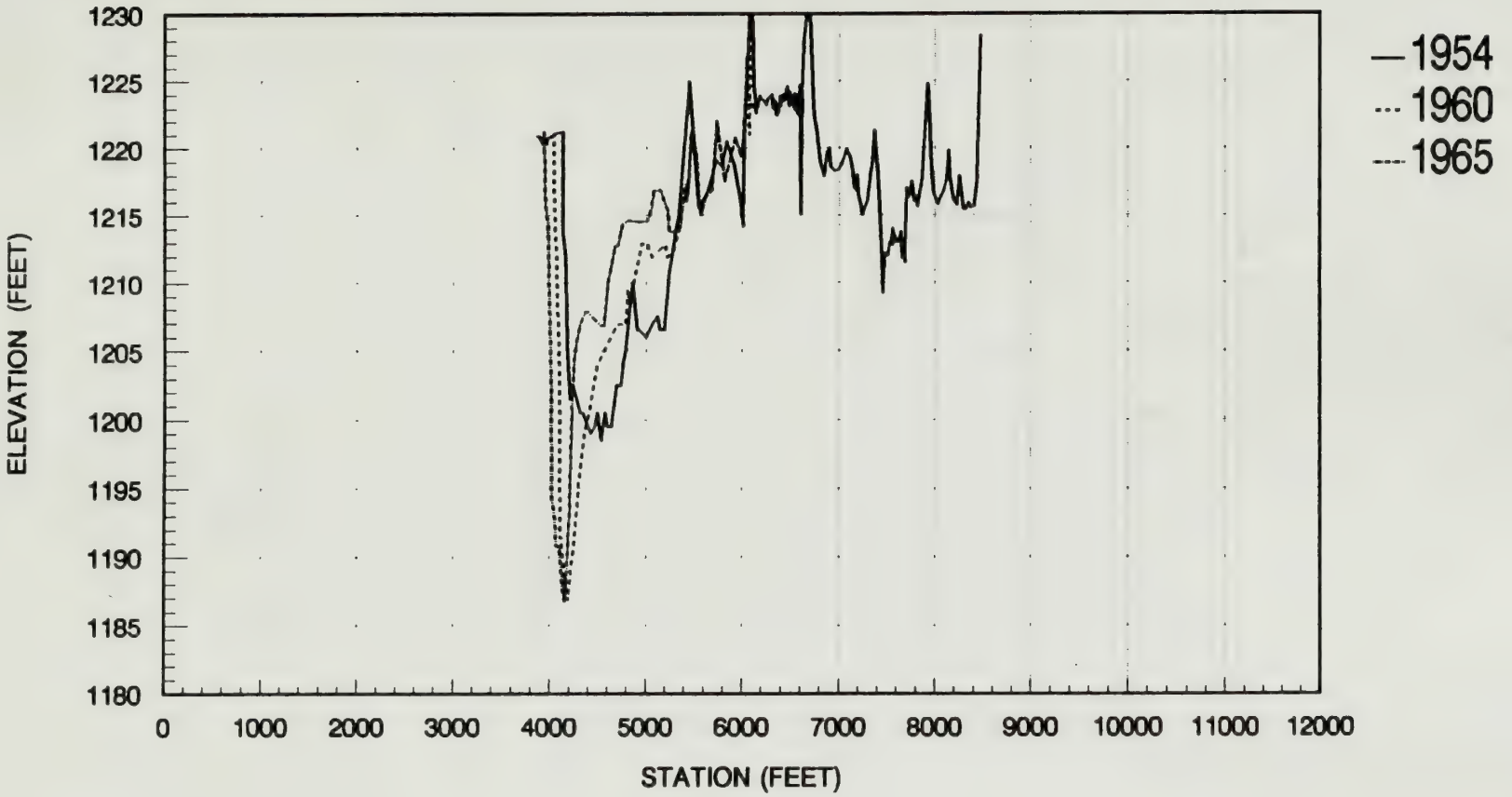
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 886.8

(1960 RIVER MILE 845.2)



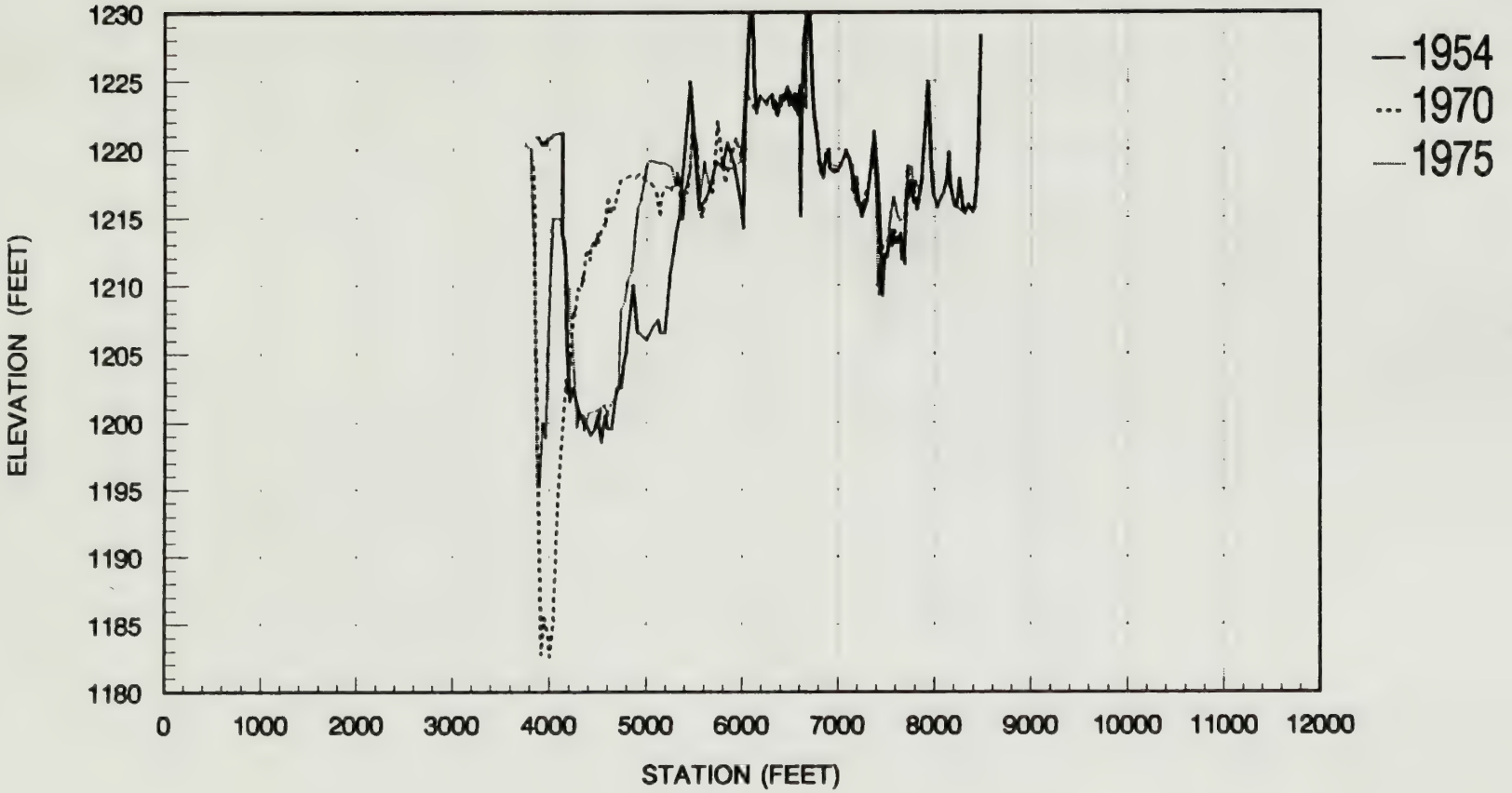
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 886.8

(1960 RIVER MILE 845.2)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 886.8

(1960 RIVER MILE 845.2)

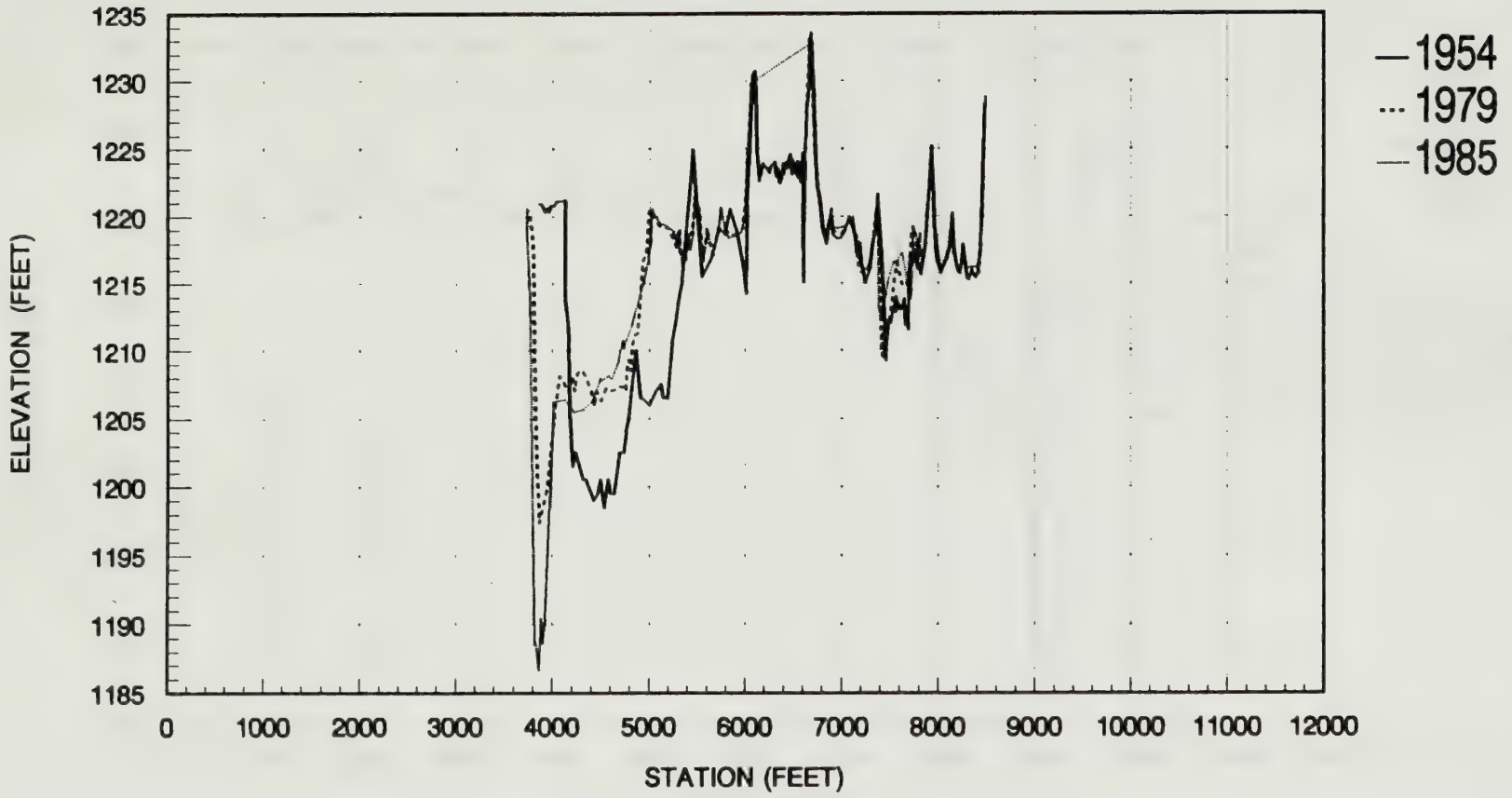


Plate III.63

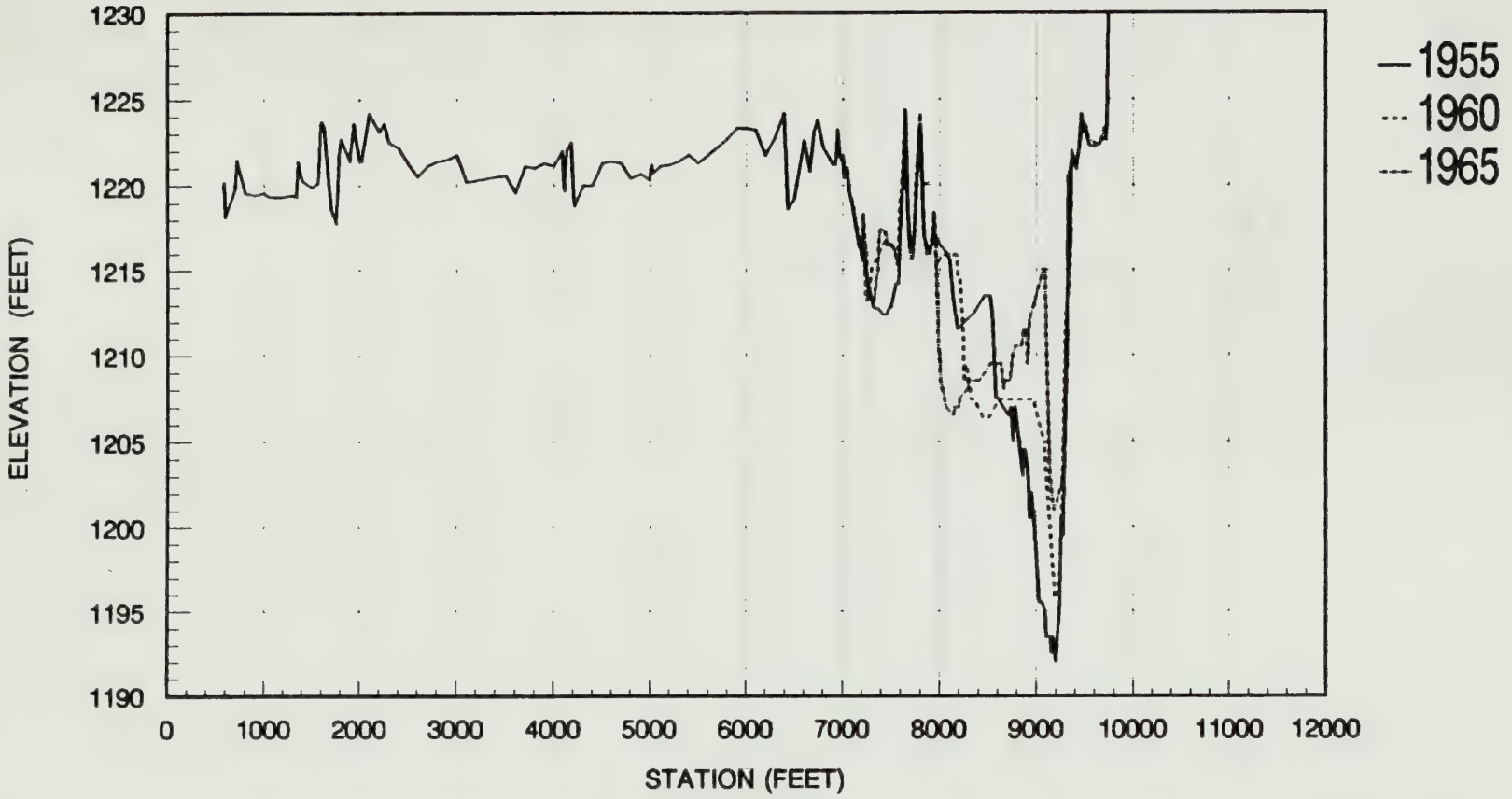
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 888.9

(1960 RIVER MILE 847.3)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

Plate III.64

CROSS SECTION PLOT FOR RANGE 888.9

(1960 RIVER MILE 847.3)

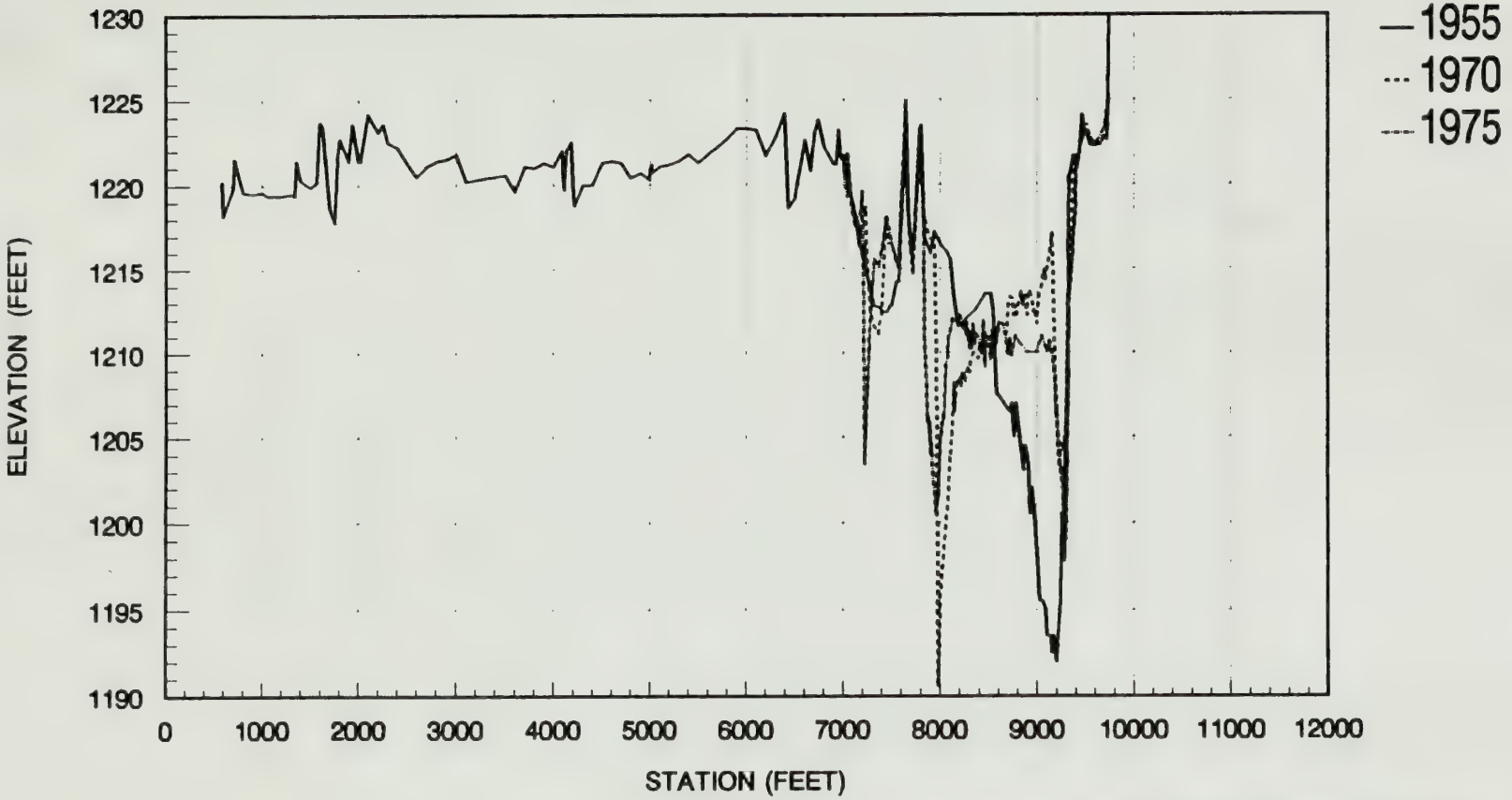


Plate III.65

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION PLOT FOR RANGE 888.9

(1960 RIVER MILE 847.3)

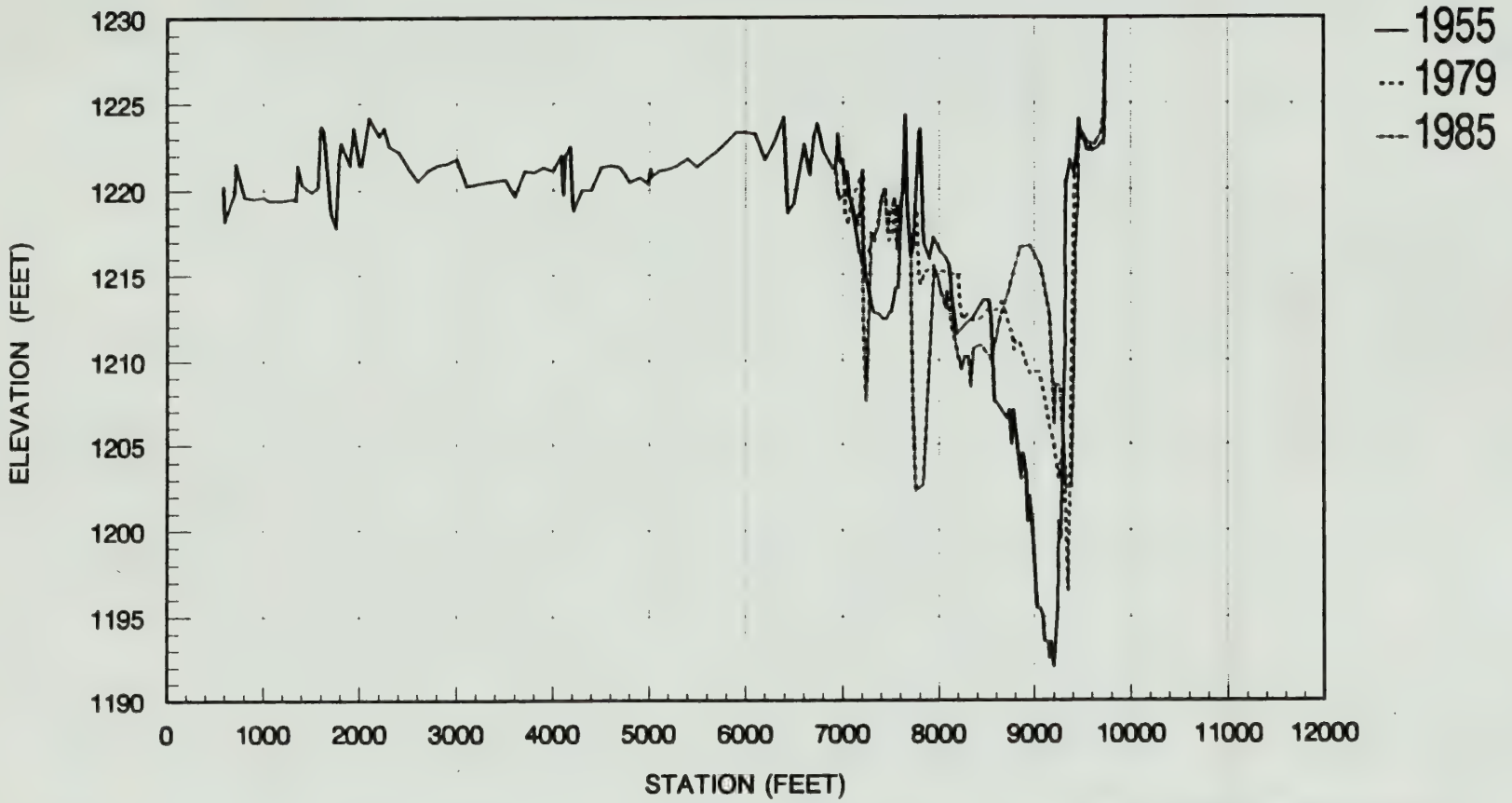


Plate III.66

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

APPENDIX IV

HYDRAULIC ELEMENT AND HYDRAULIC PARAMETER PLOTS

NIOBRARA RIVER RANGE N 0.0

CHANNEL WIDTH (W) AT GIVEN ELEVATION

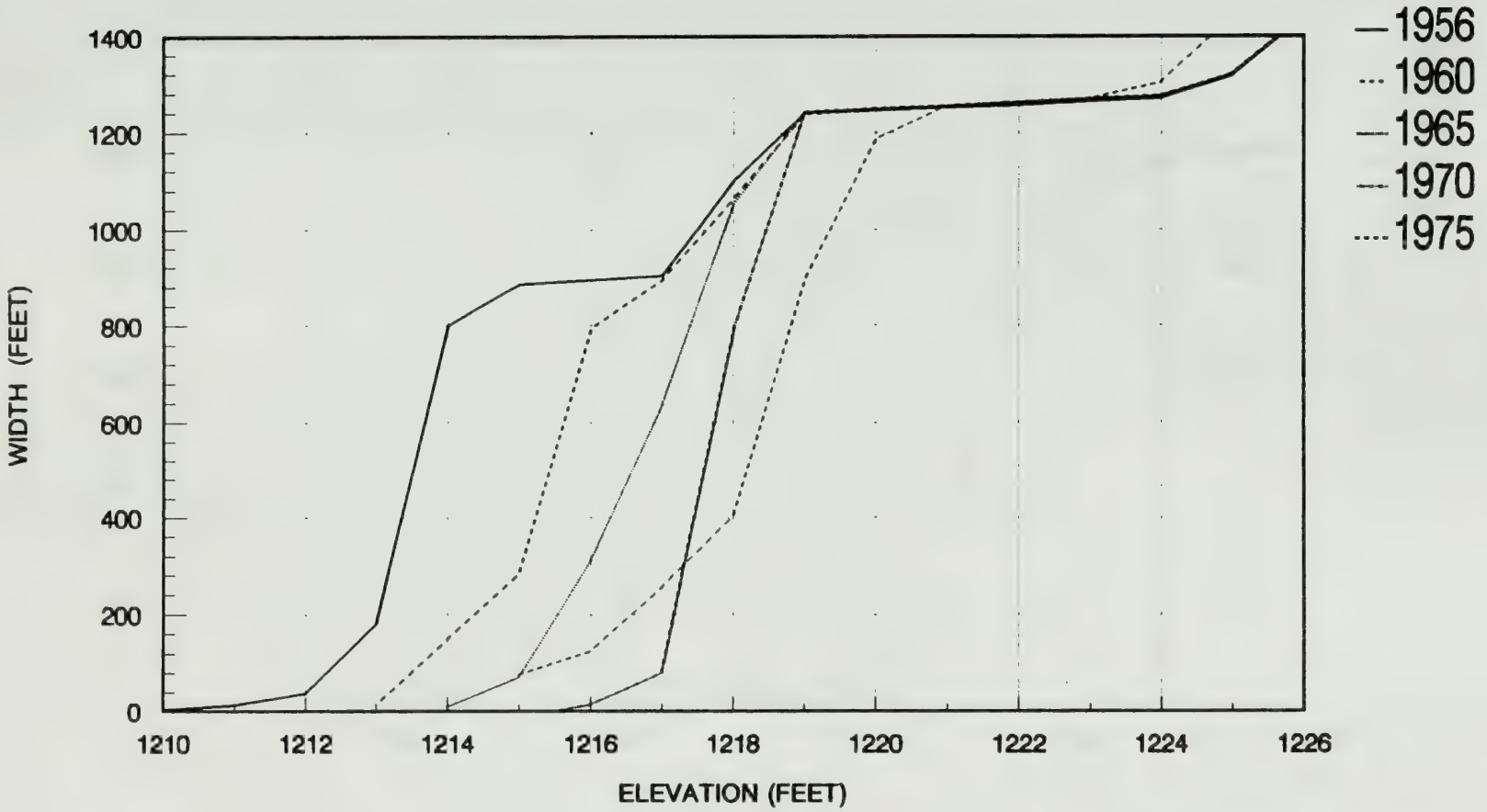


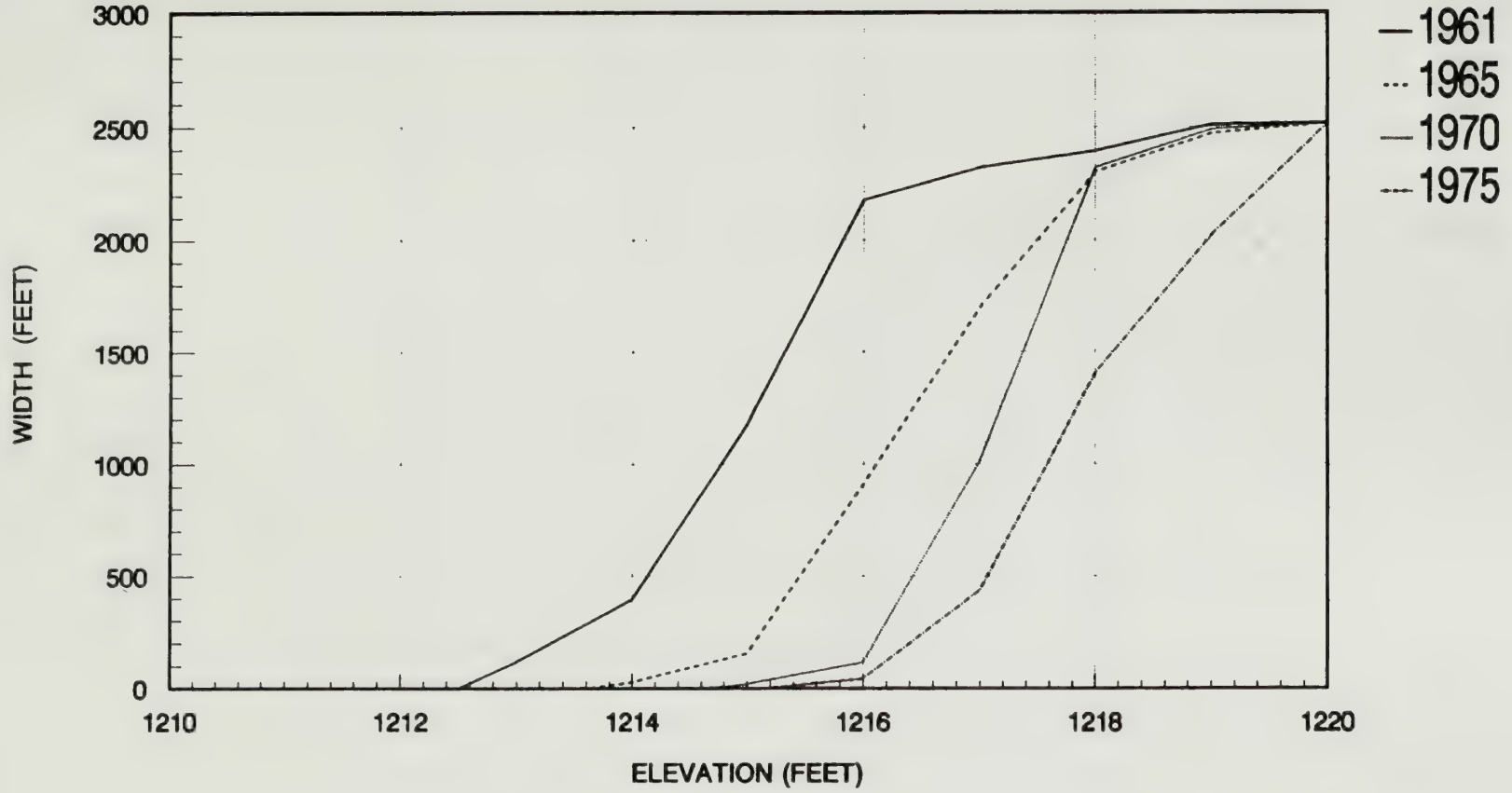
Plate IV.1

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 0.1
CHANNEL WIDTH (W) AT GIVEN ELEVATION



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

Plate IV.2

NIOBRARA RIVER RANGE N 0.5

CHANNEL WIDTH (W) AT GIVEN ELEVATION

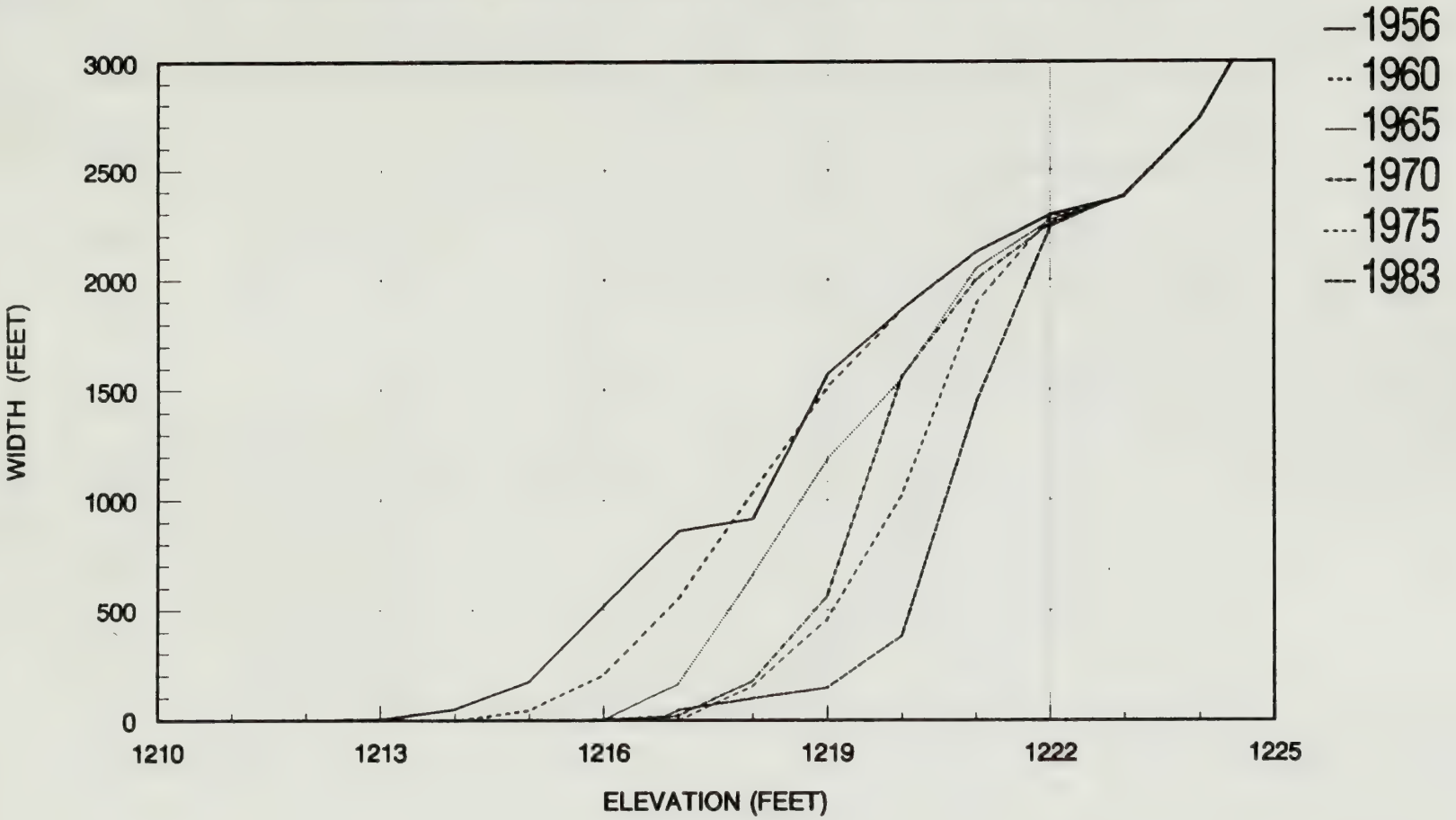


Plate IV.3

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

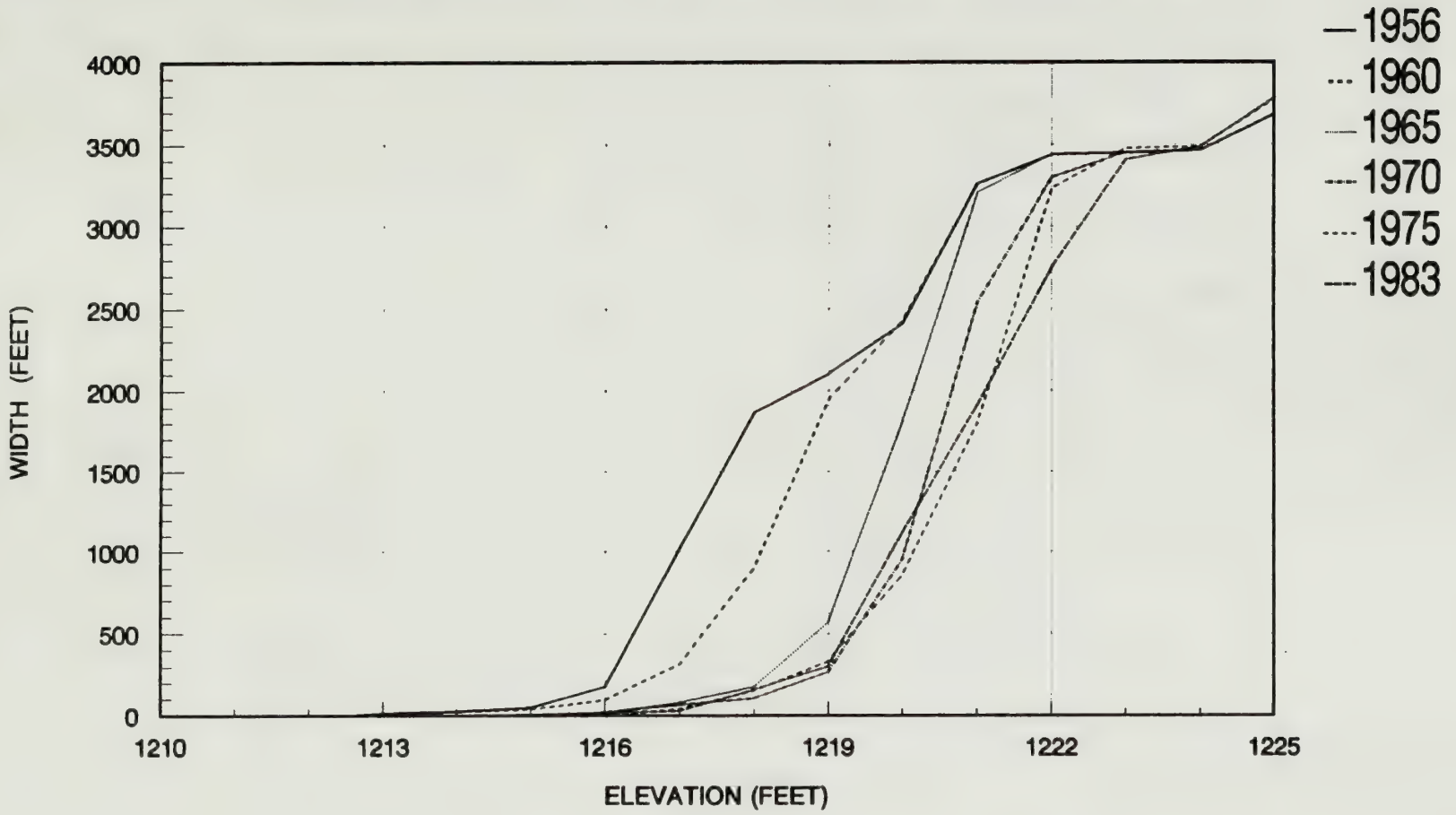


Plate IV.4

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 1.1

CHANNEL WIDTH (W) AT GIVEN ELEVATION

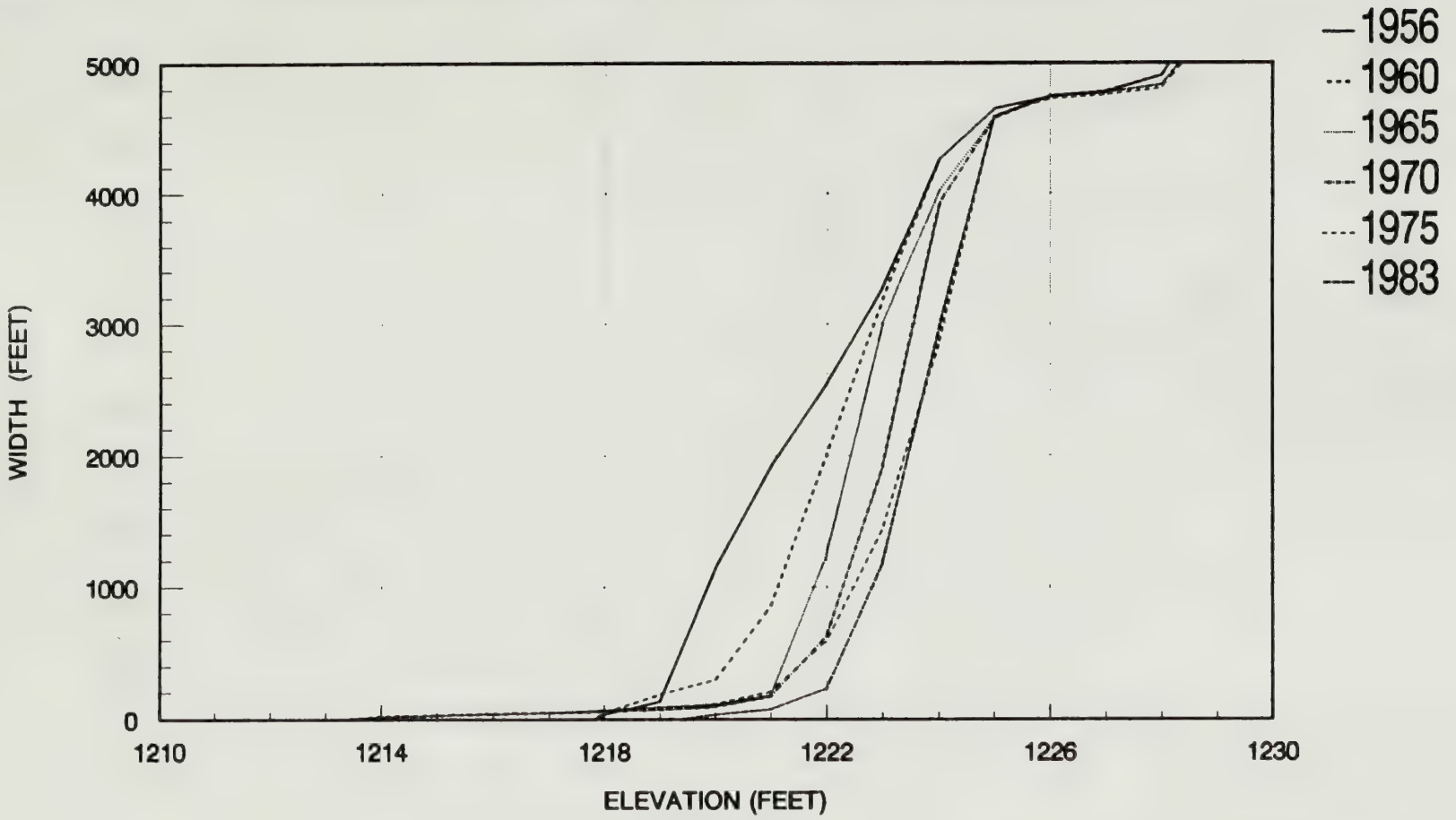


Plate IV.5

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

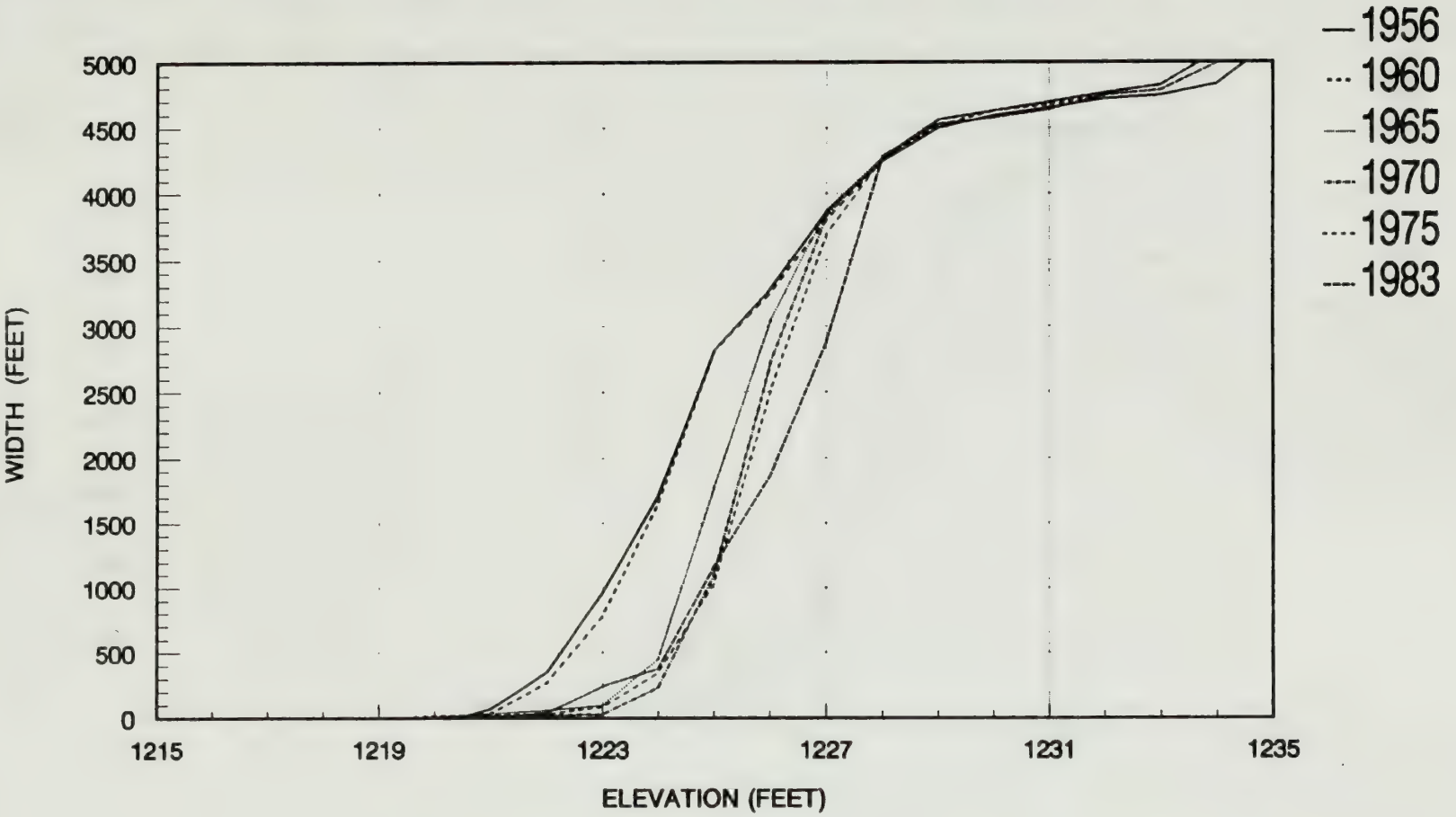


Plate IV.6

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

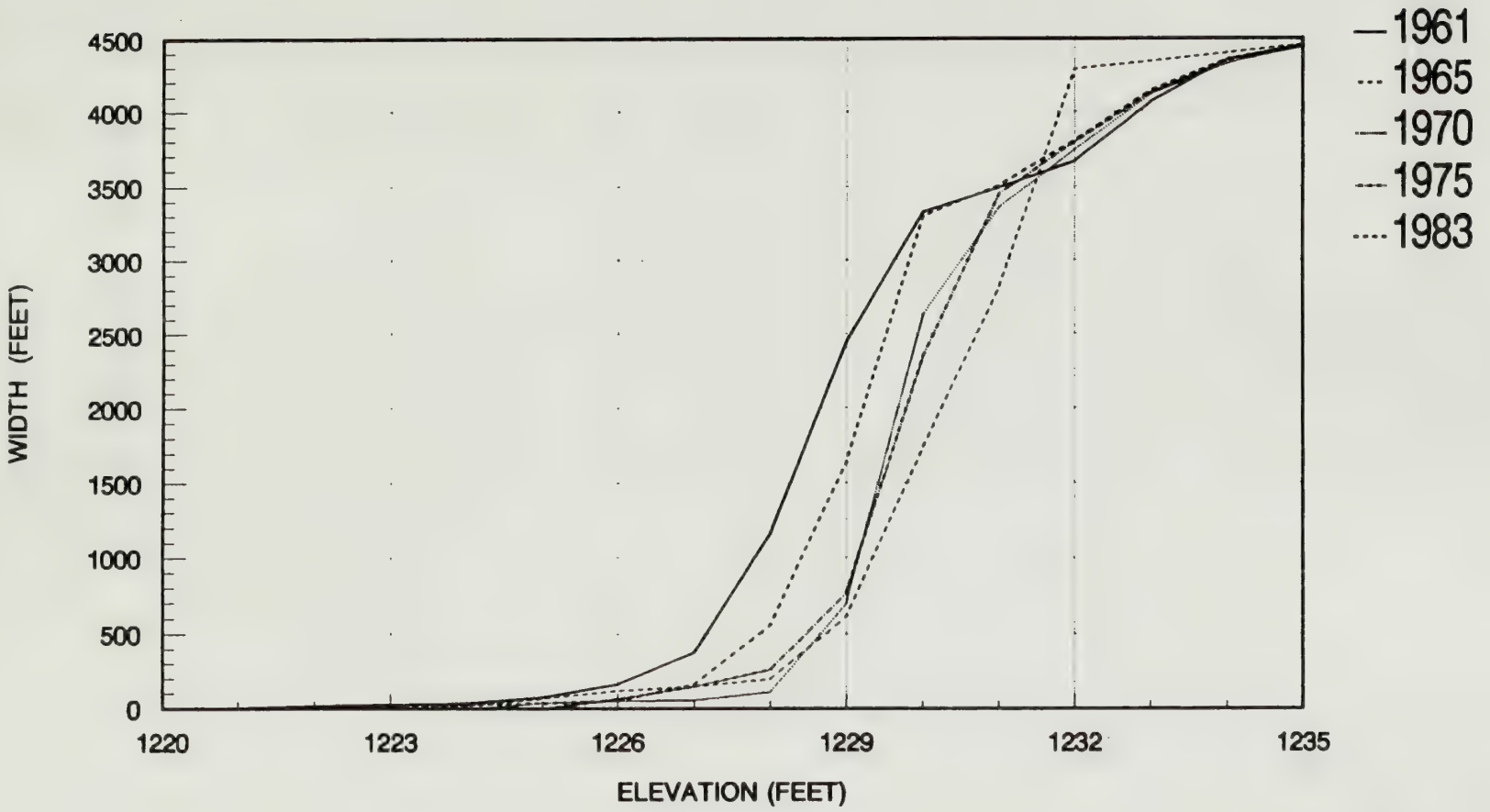


Plate IV.7

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

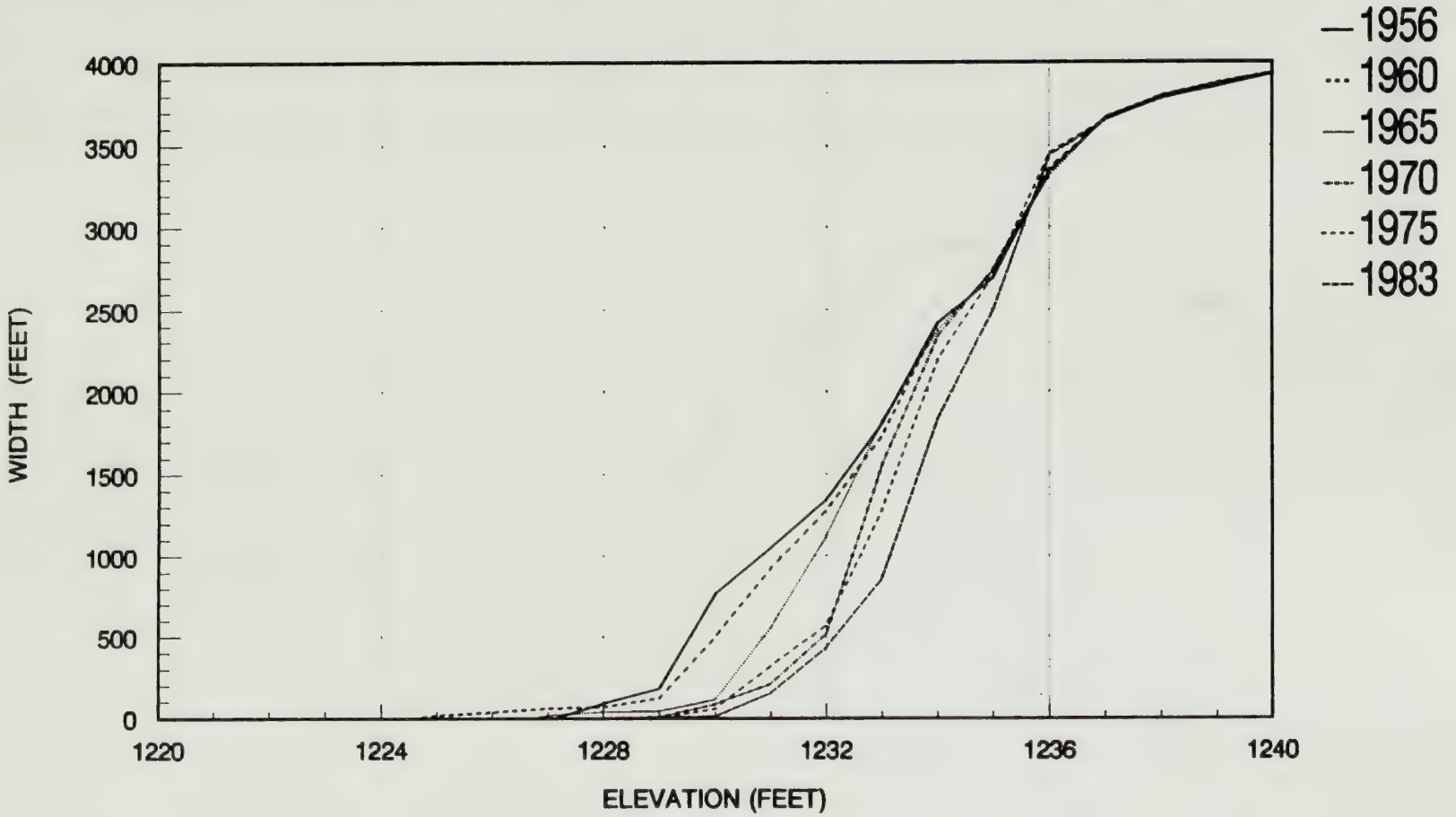


Plate IV.8

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

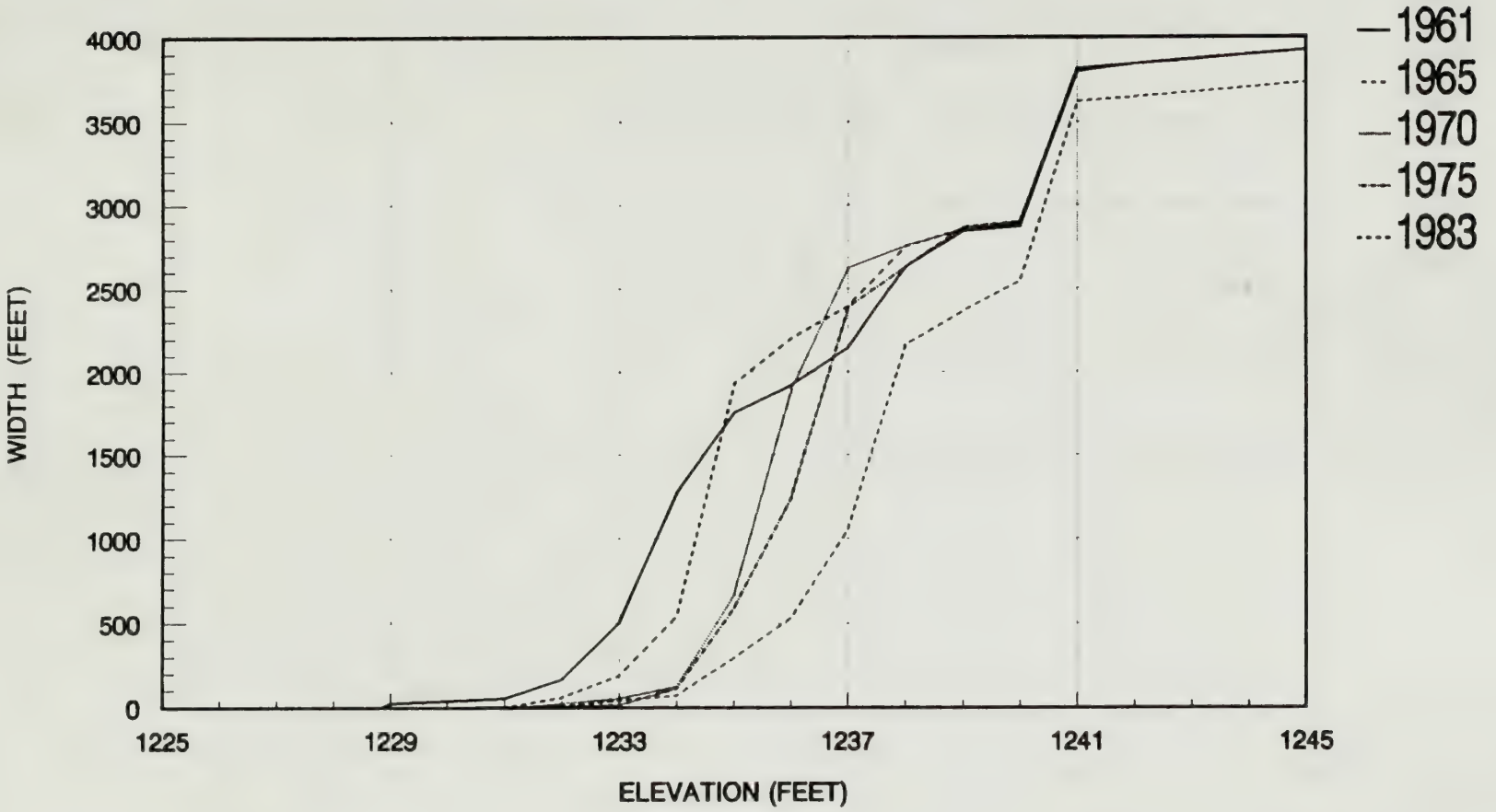


Plate IV.9

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

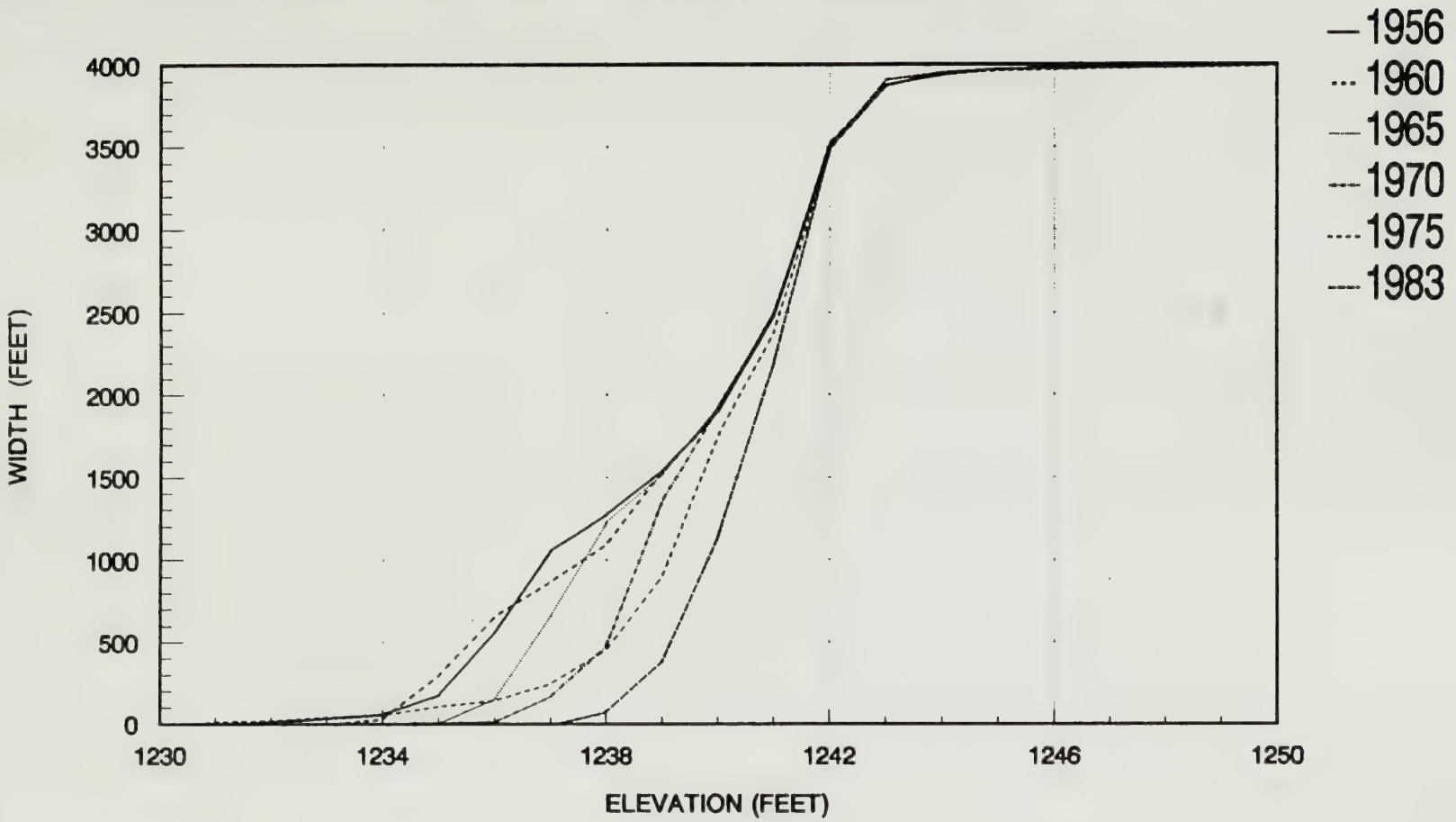


Plate IV.10

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

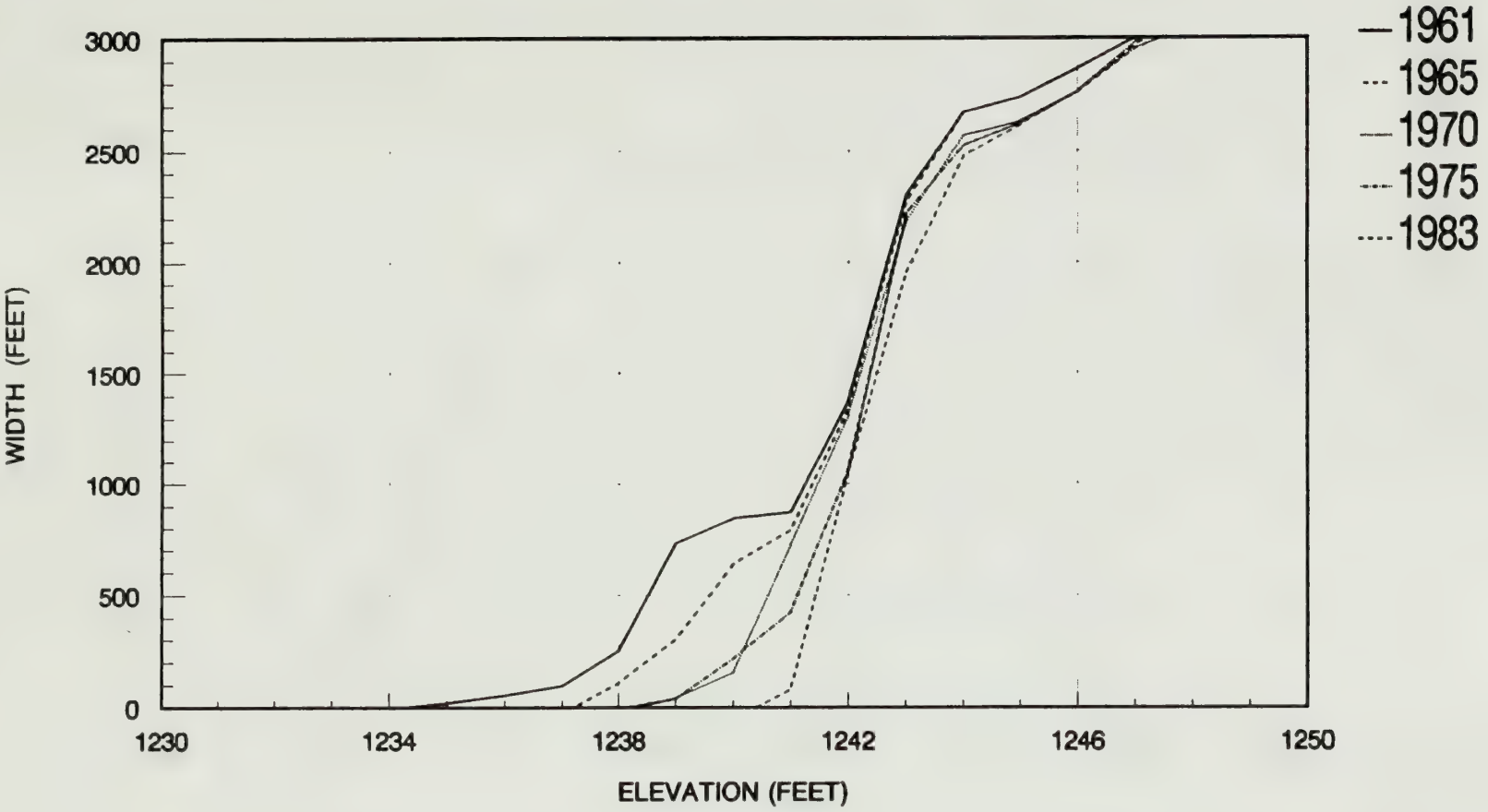


Plate IV.11

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

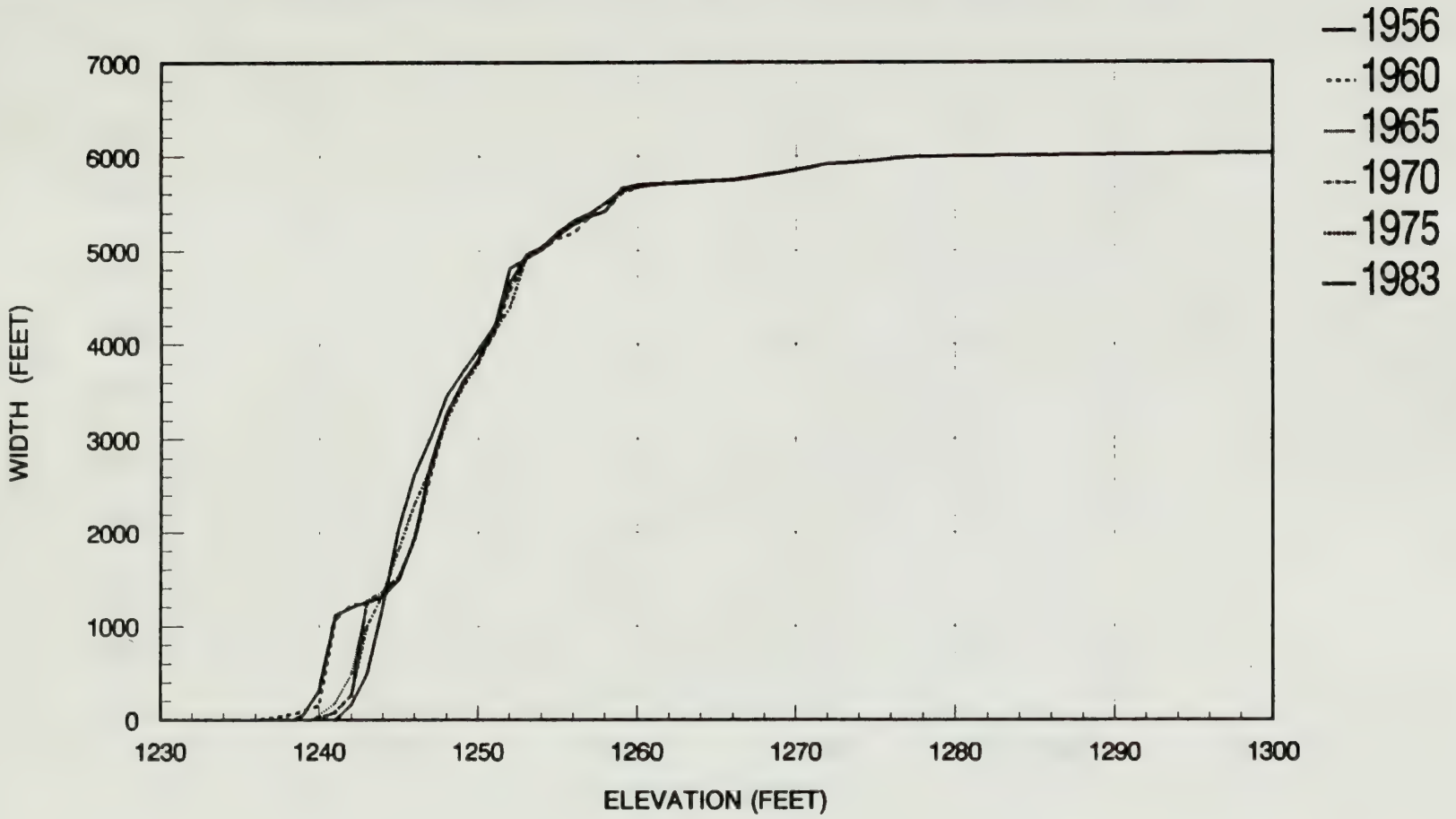


Plate IV.12

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

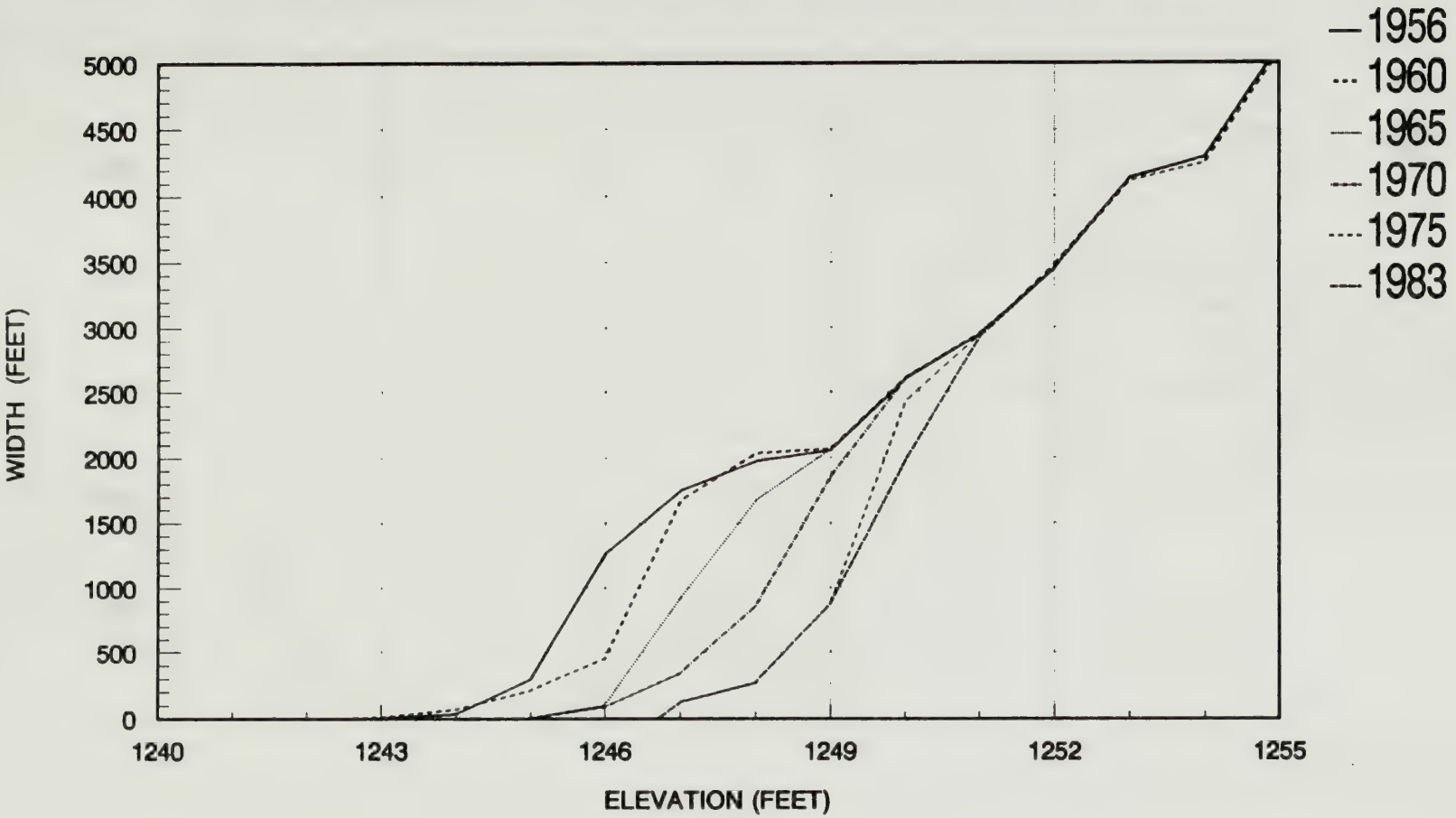


Plate IV.13

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

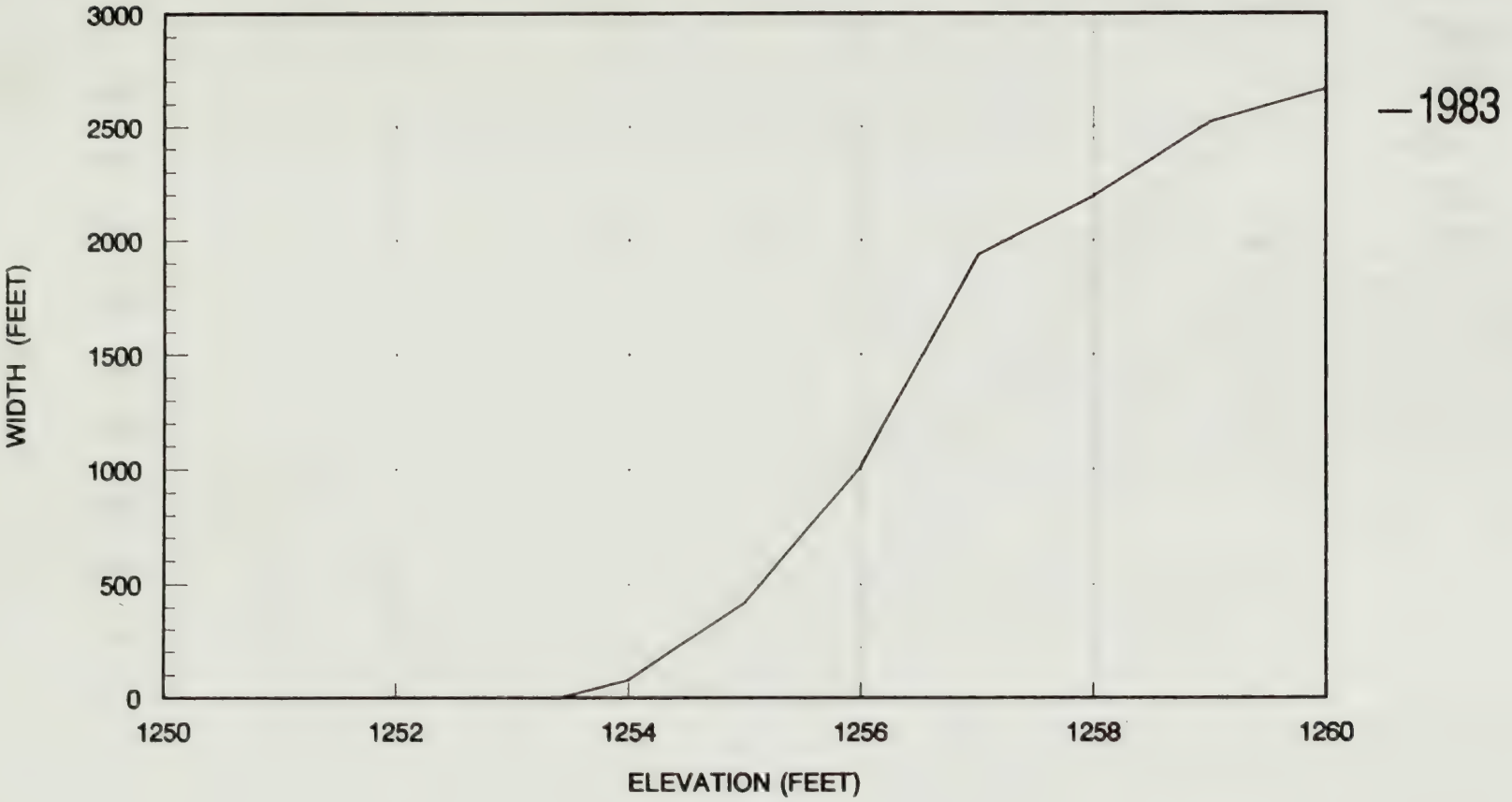


Plate IV.14

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 6.9
CHANNEL WIDTH (W) AT GIVEN ELEVATION

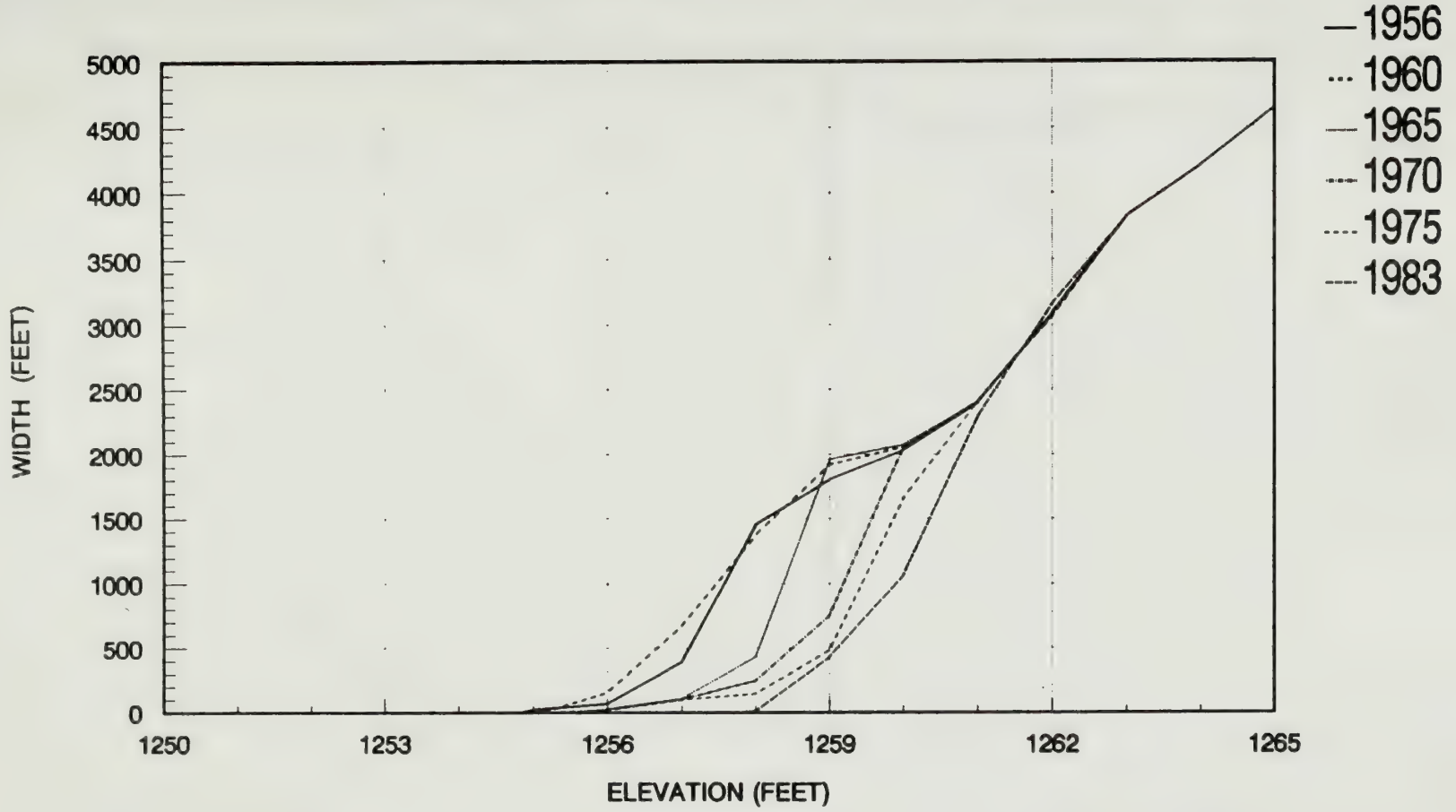


Plate IV.15

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

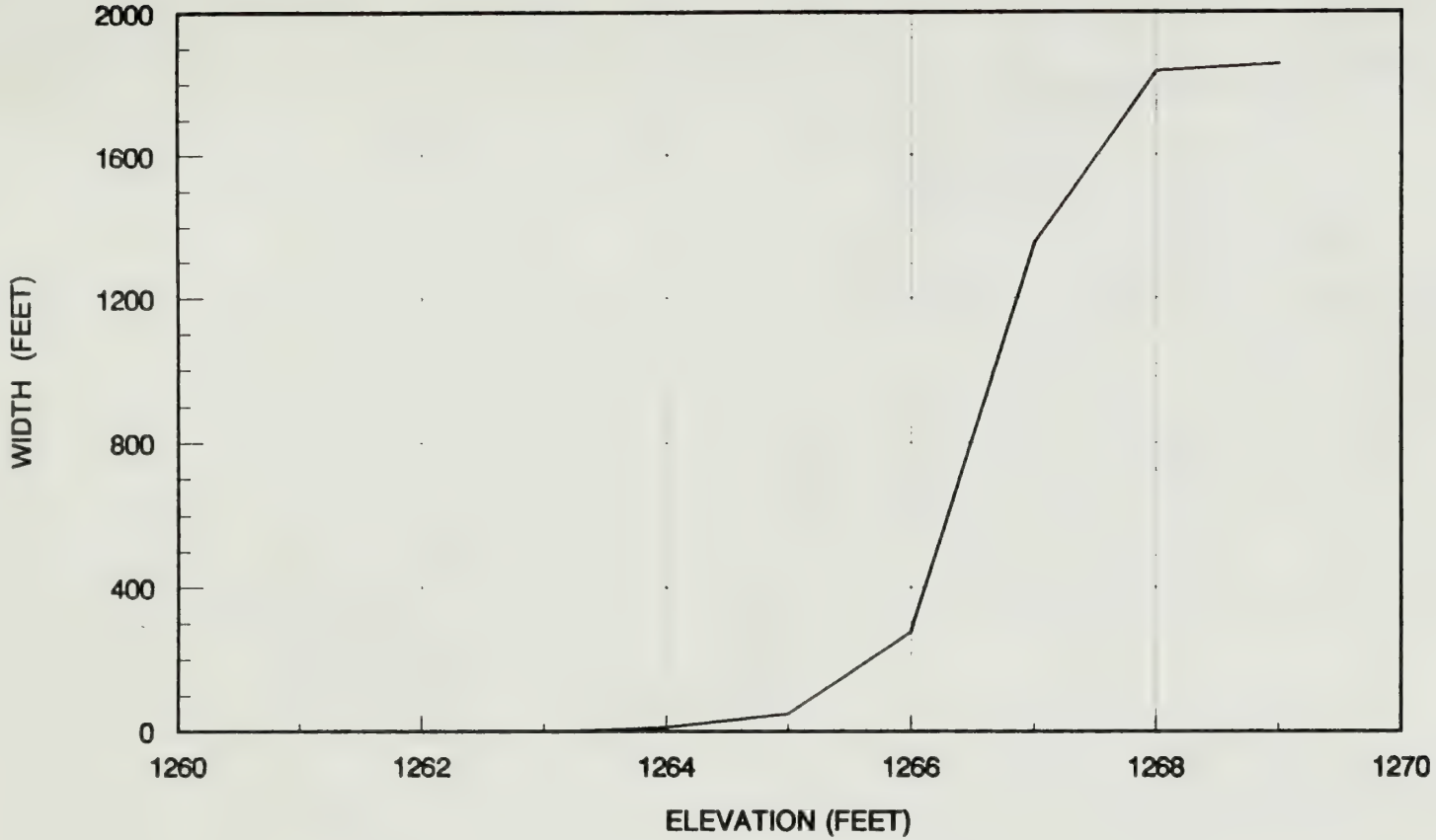


Plate IV.16

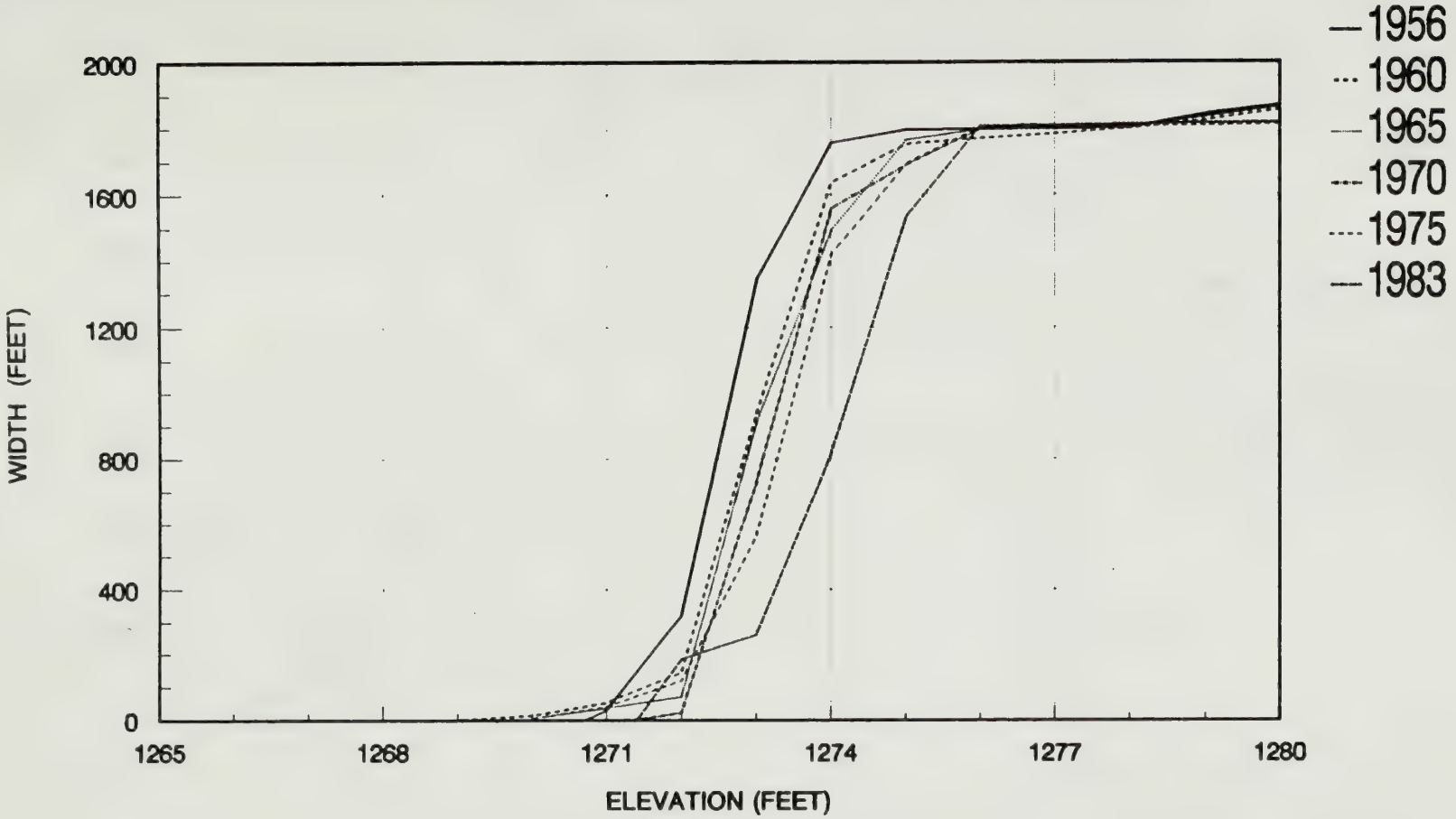
NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 9.0

CHANNEL WIDTH (W) AT GIVEN ELEVATION



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

Plate IV.17

CHANNEL WIDTH (W) AT GIVEN ELEVATION

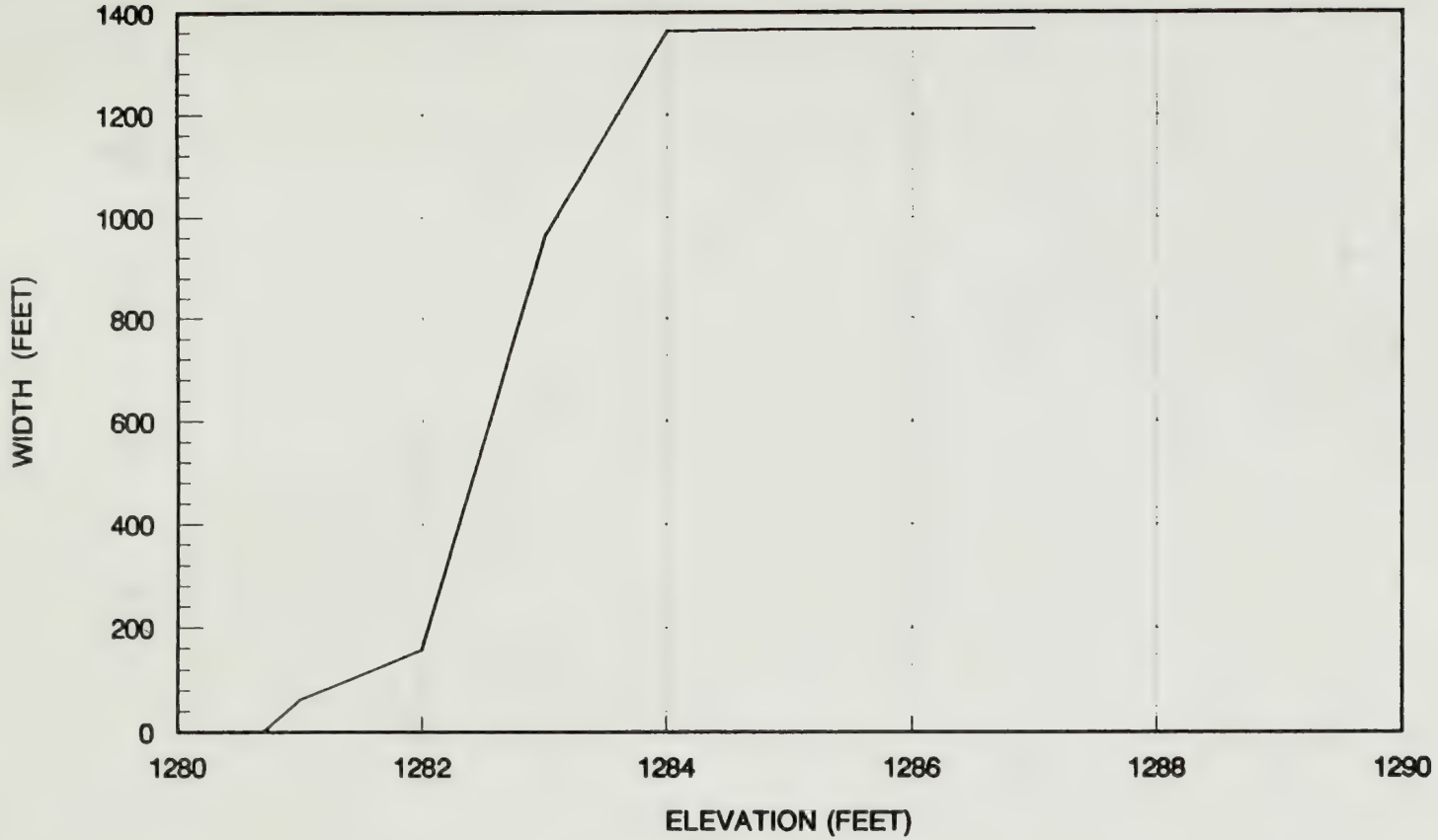


Plate IV.18

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

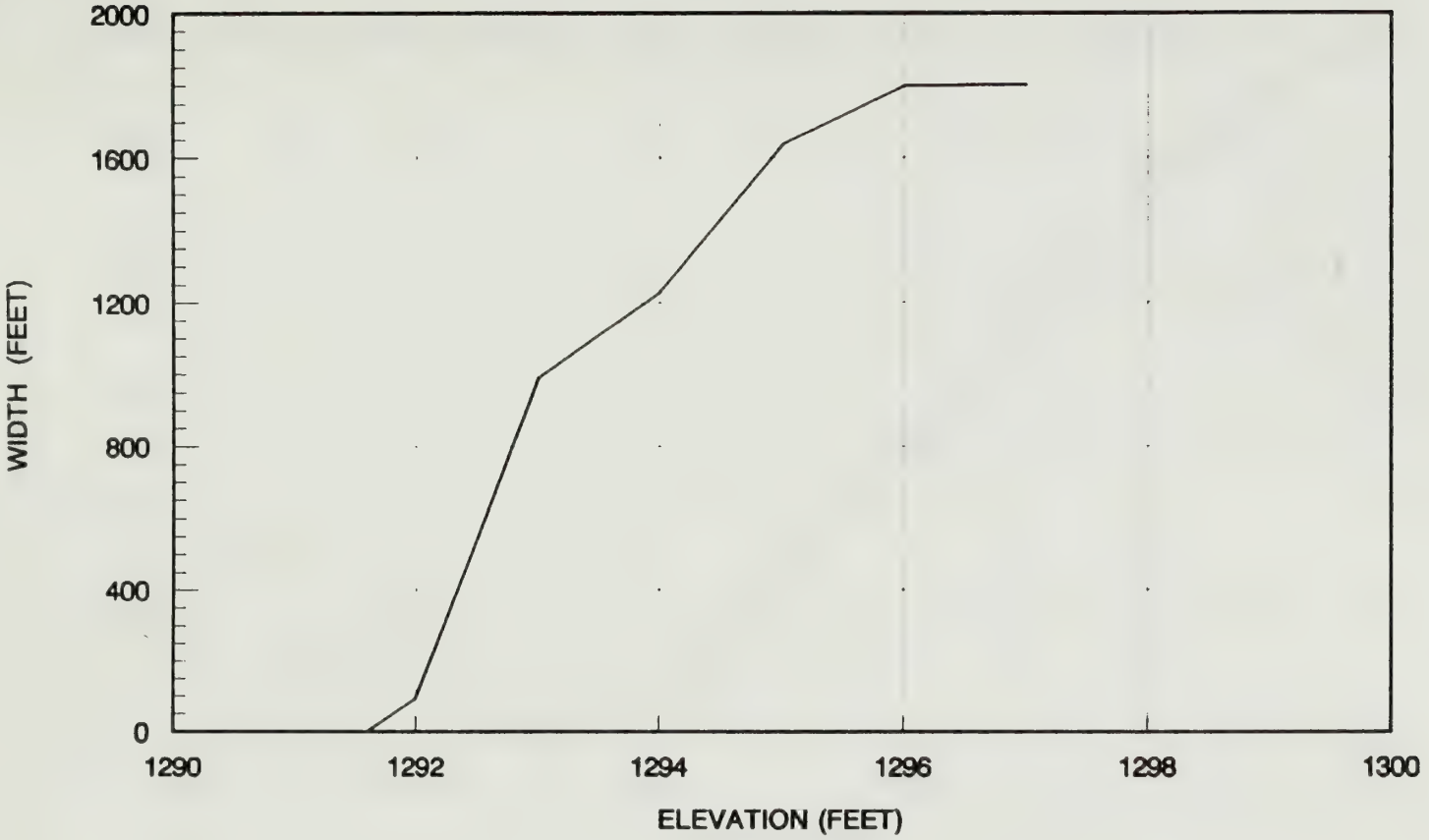


Plate IV.19

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

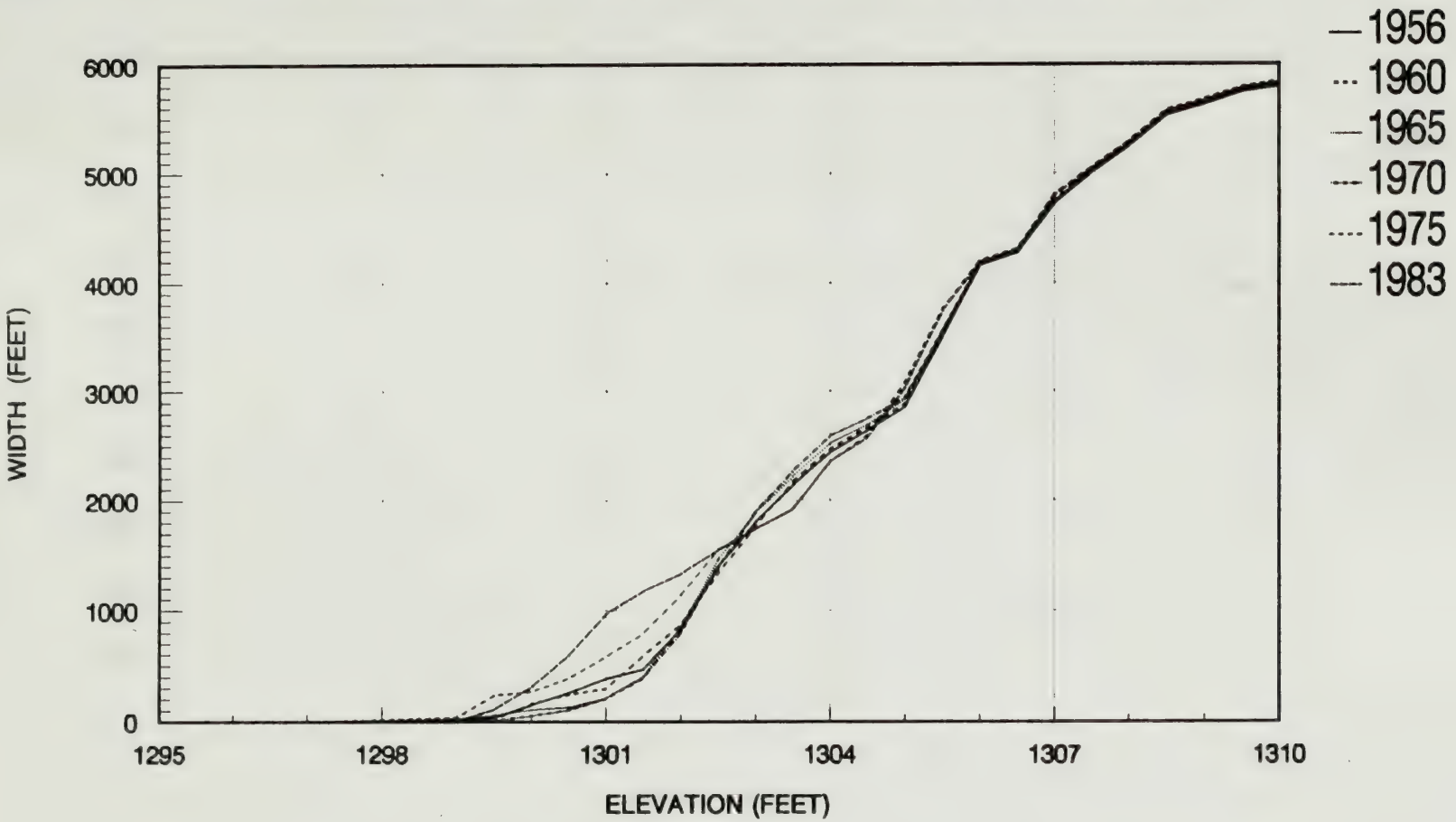


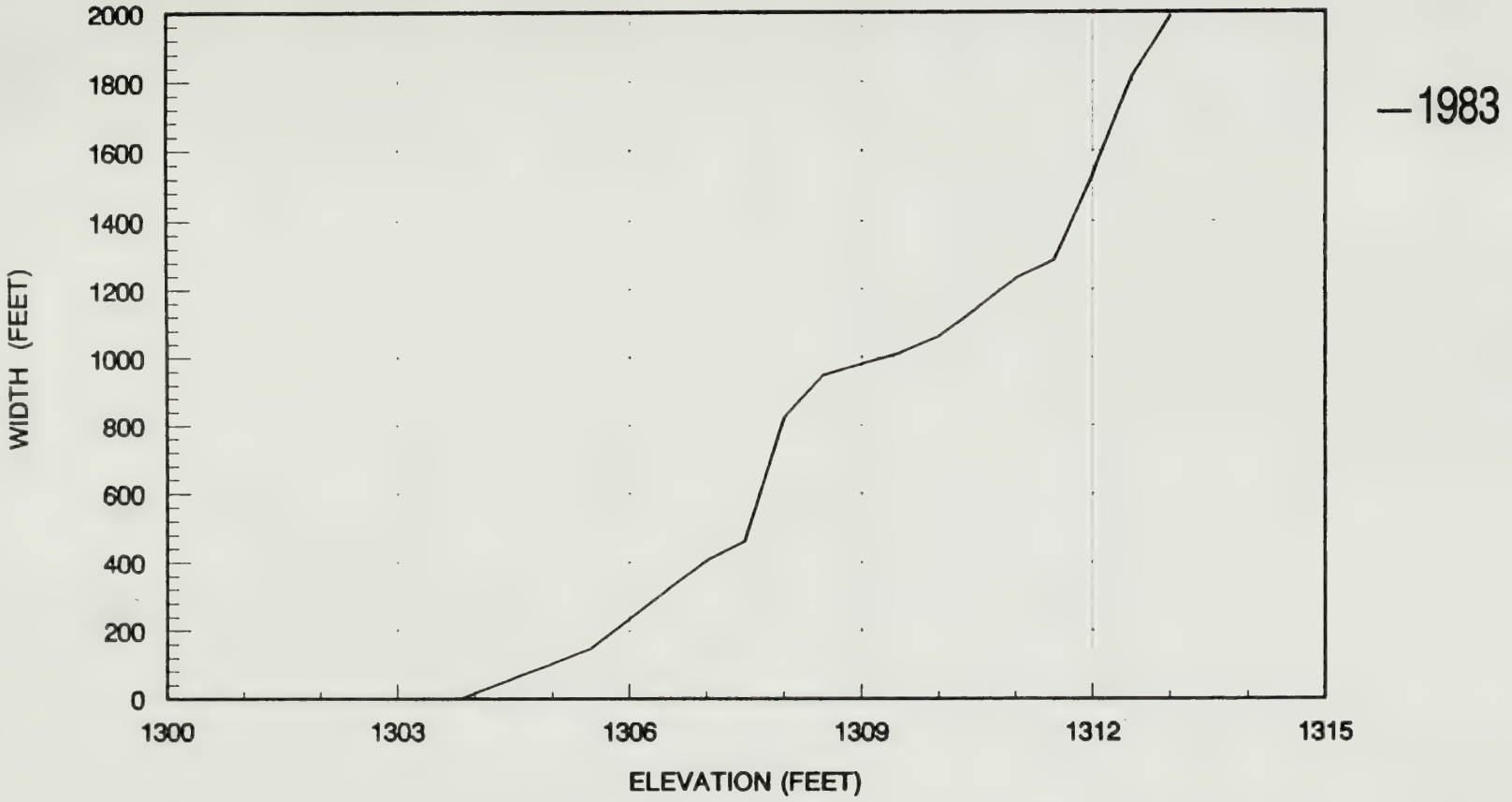
Plate IV.20

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N13.8
CHANNEL WIDTH (W) AT GIVEN ELEVATION

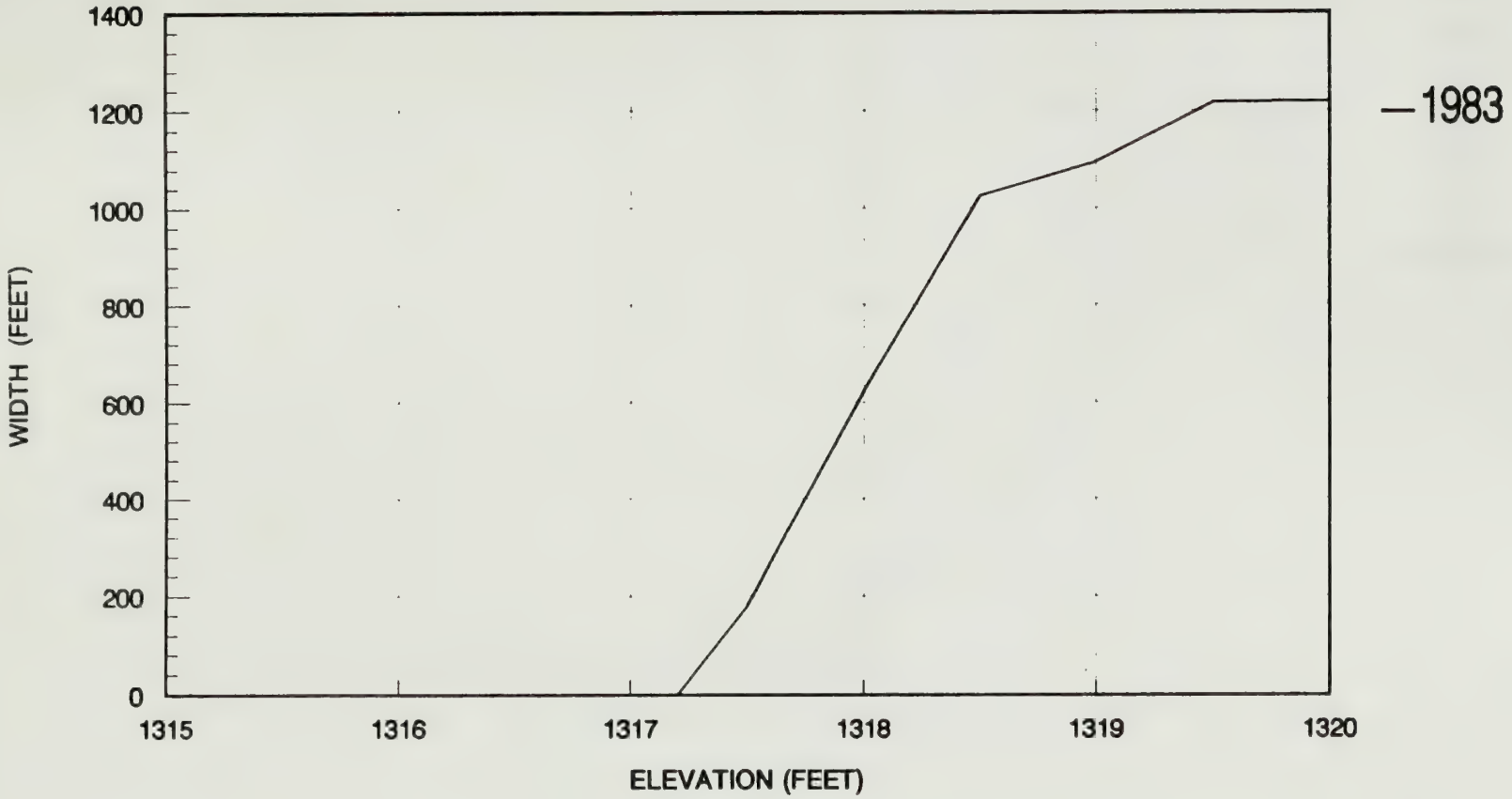


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION

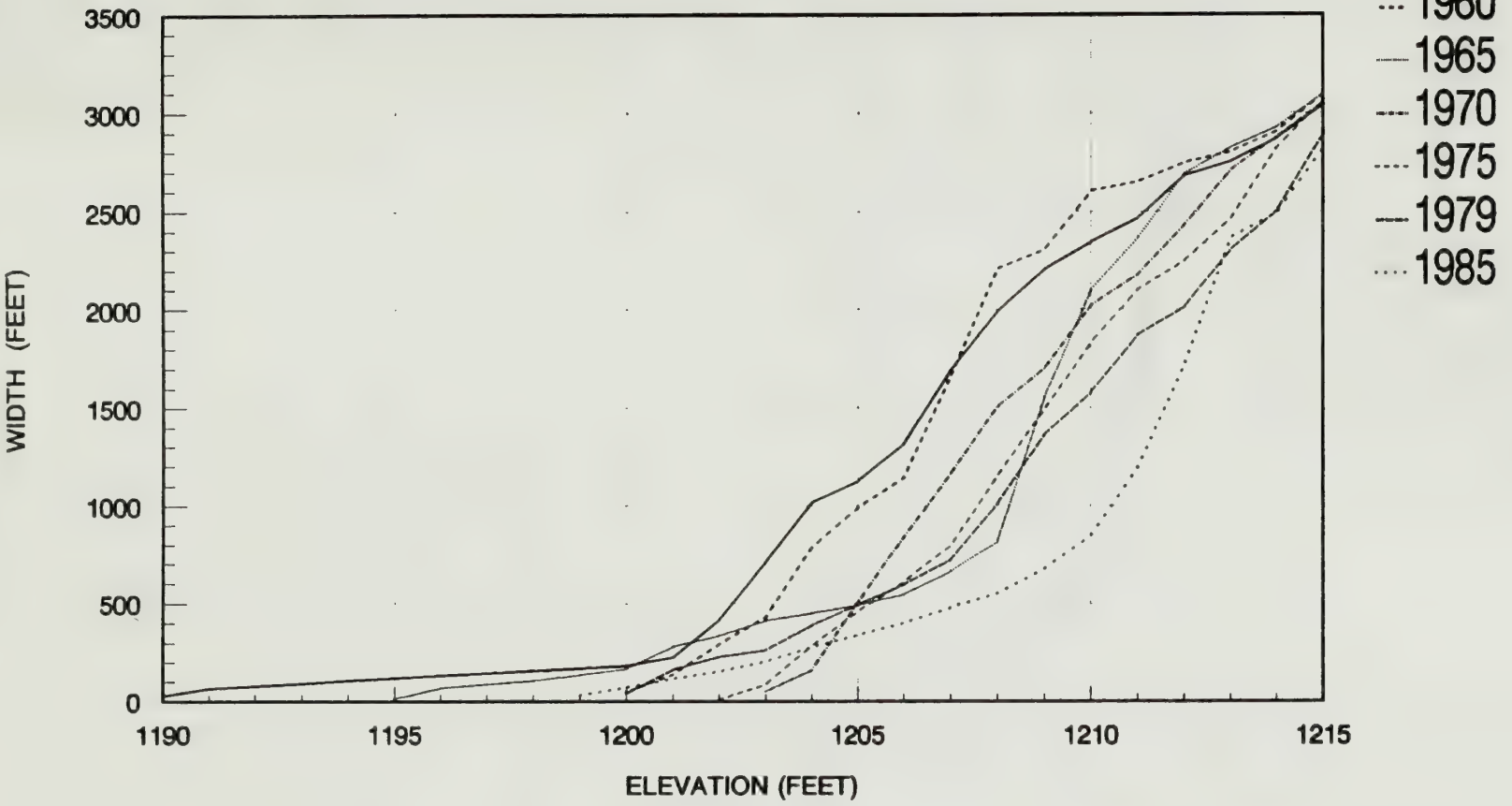


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION
(1960 RIVERMILE 846.0)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION
(1960 RIVERMILE 840.6)

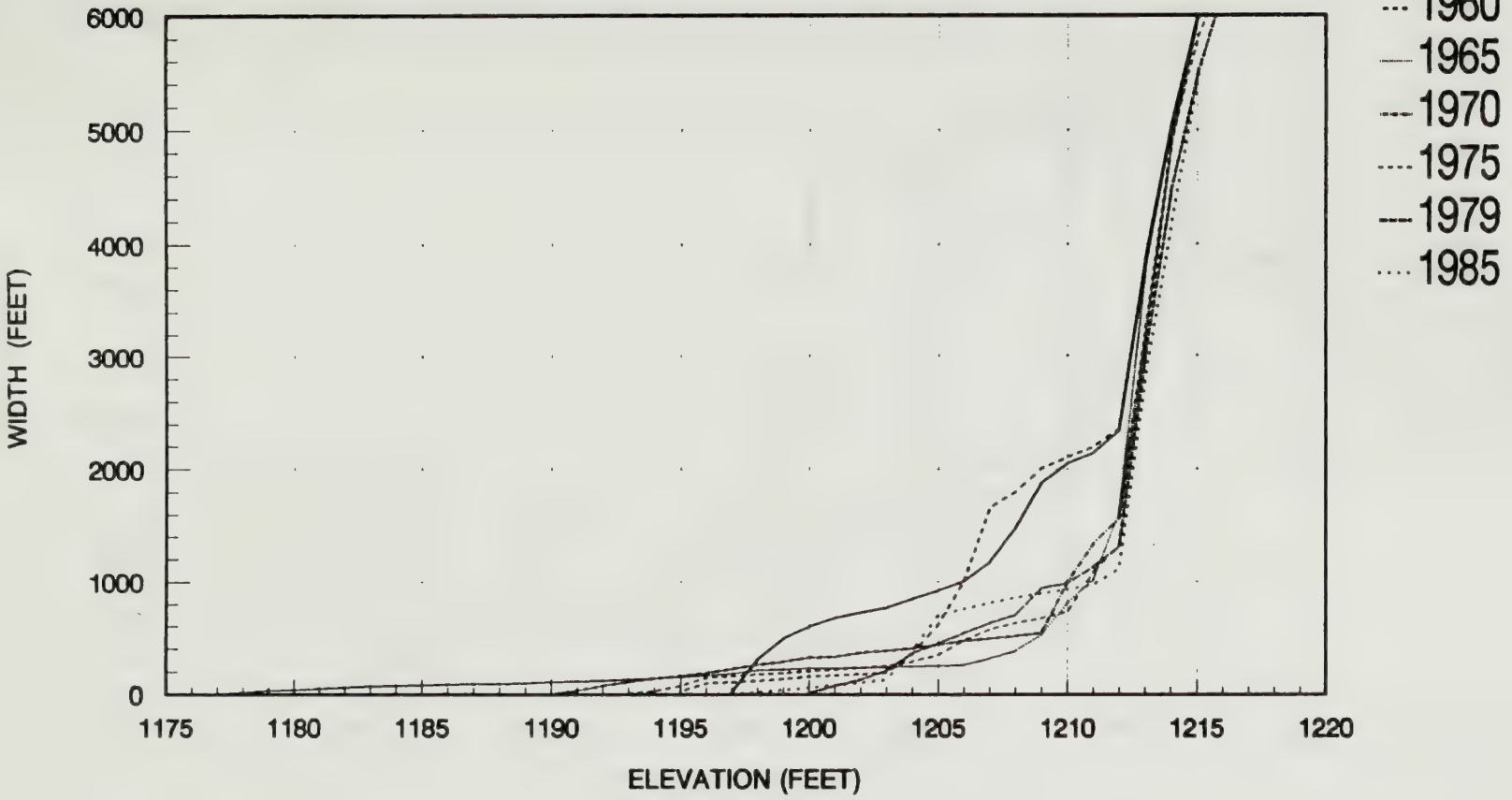


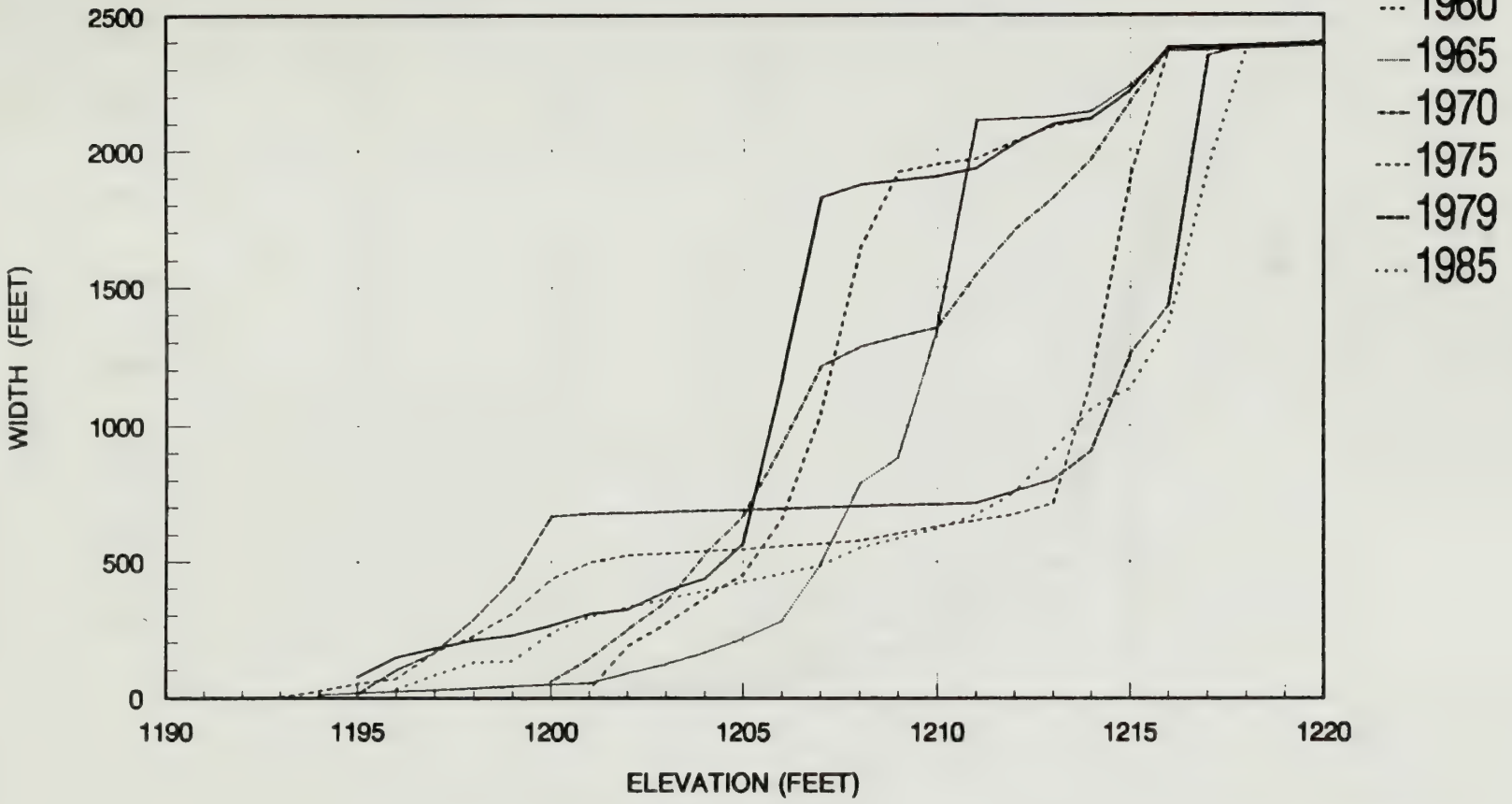
Plate IV.24

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION
(1960 RIVERMILE 841.2)



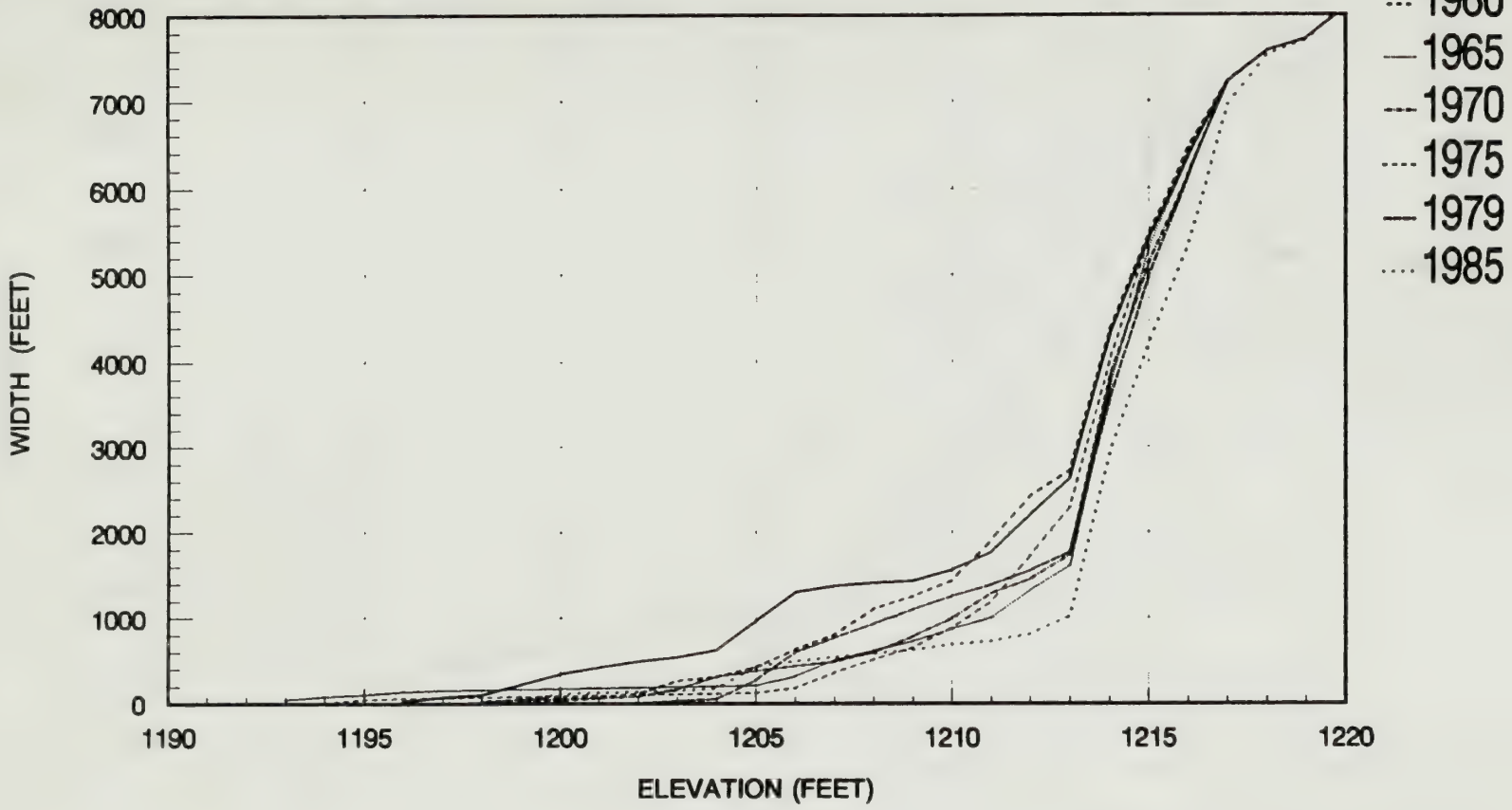
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER BASIC 880.5

CHANNEL WIDTH (W) AT GIVEN ELEVATION
(1960 RIVERMILE 841.9)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 8[illegible]

CHANNEL WIDTH (W) AT GIVEN ELEVATION
(1960 RIVERMILE 842.4)

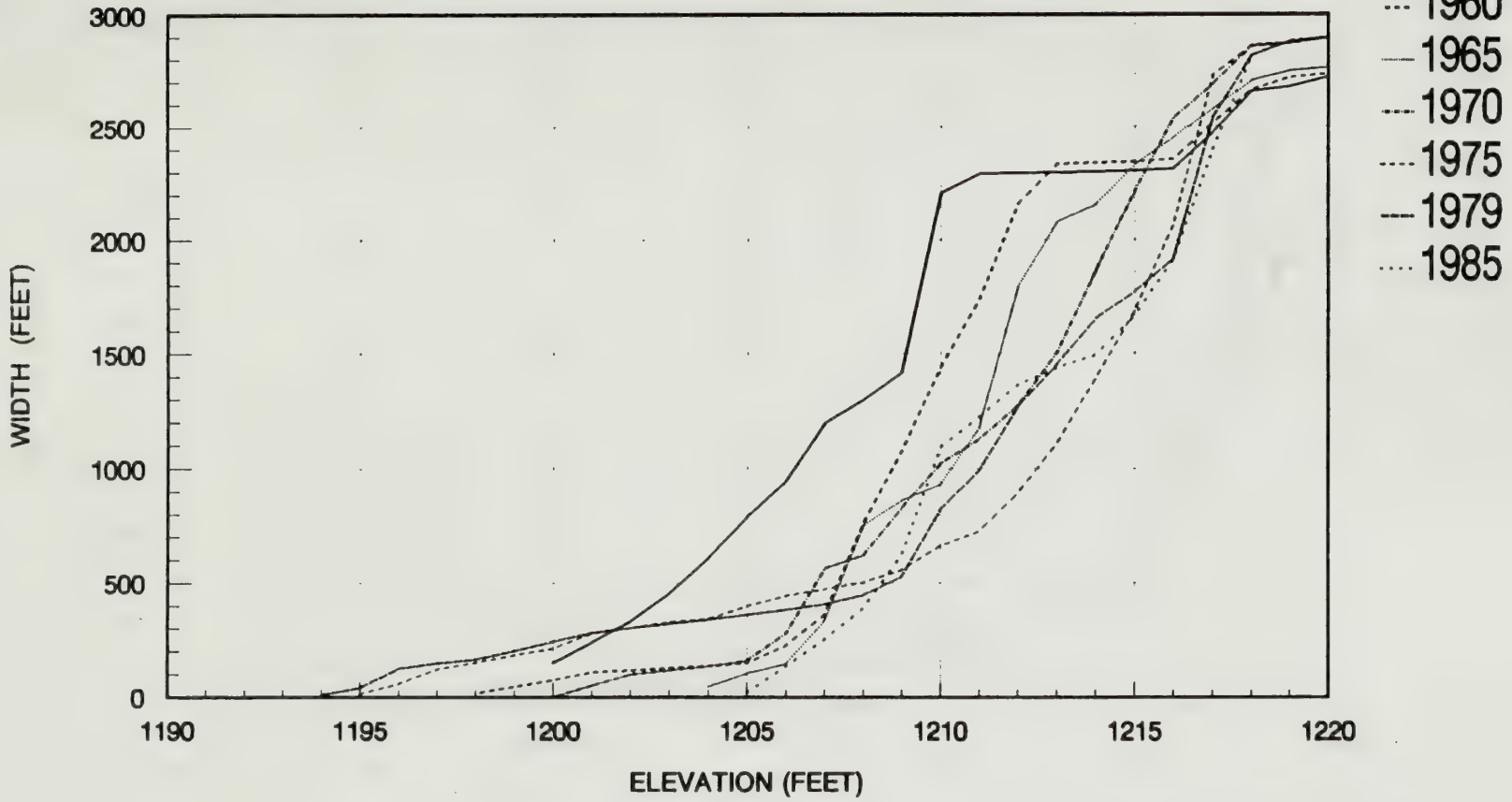


Plate IV.27

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION
(1960 RIVERMILE 842.9)

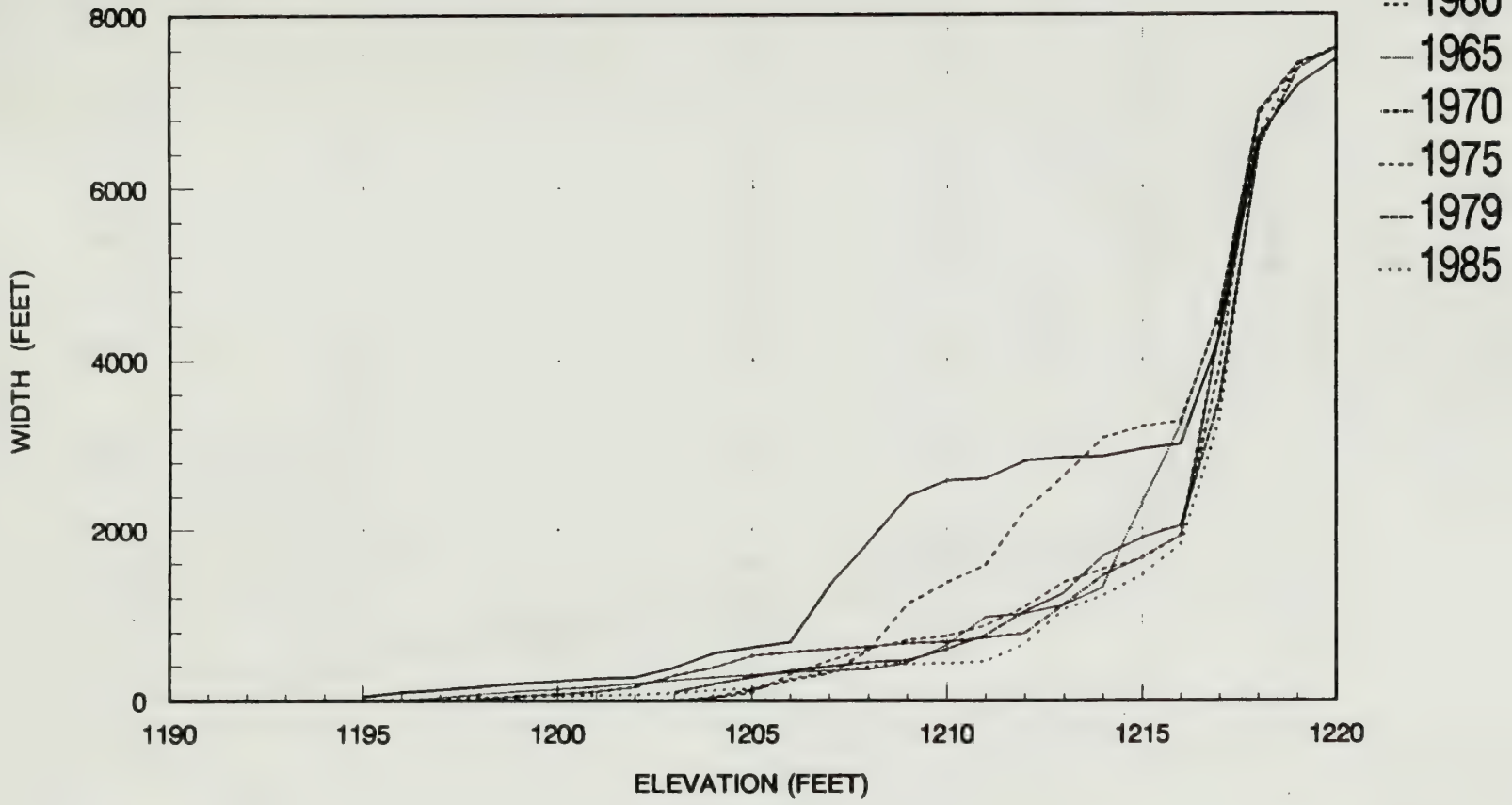
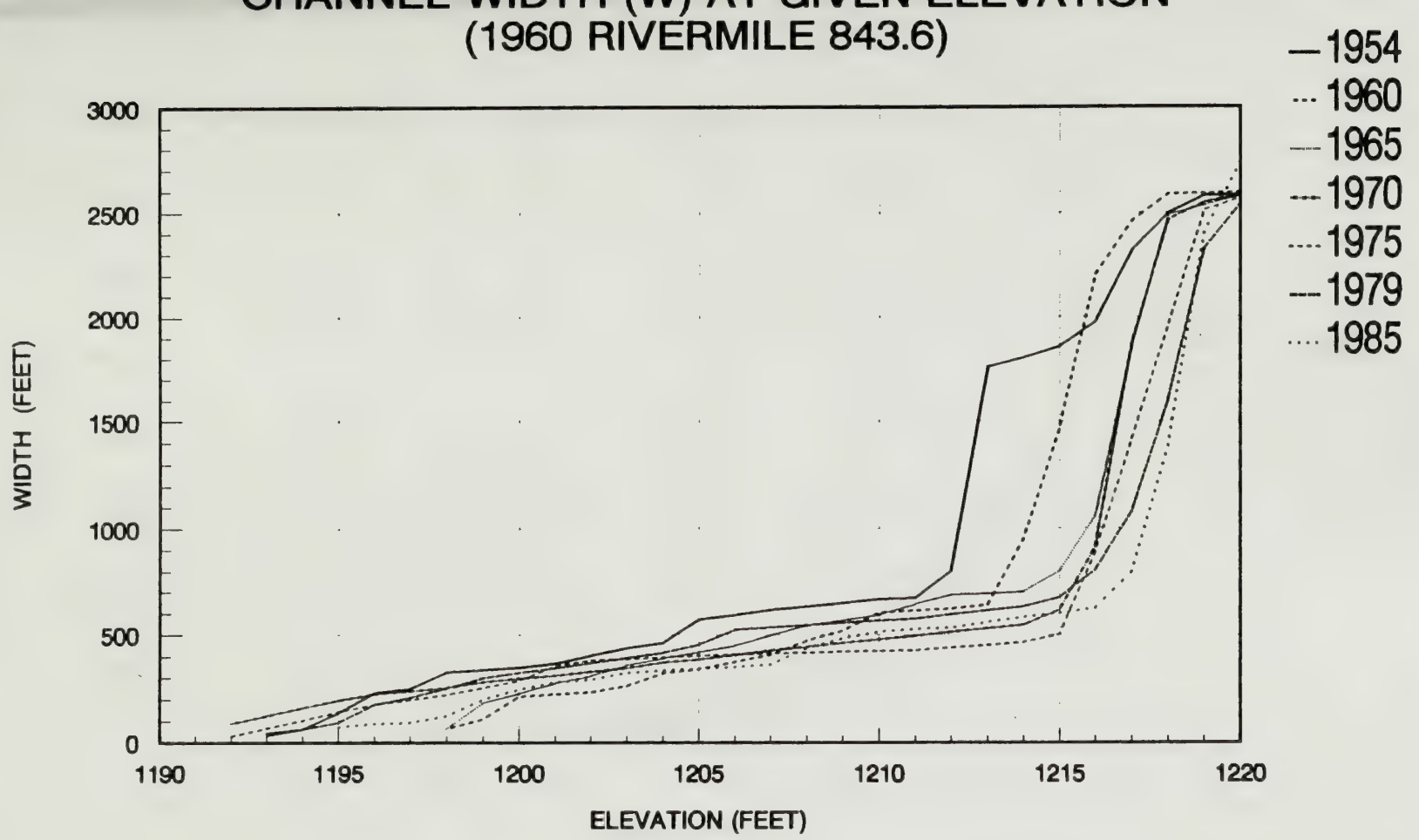


Plate IV.28

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

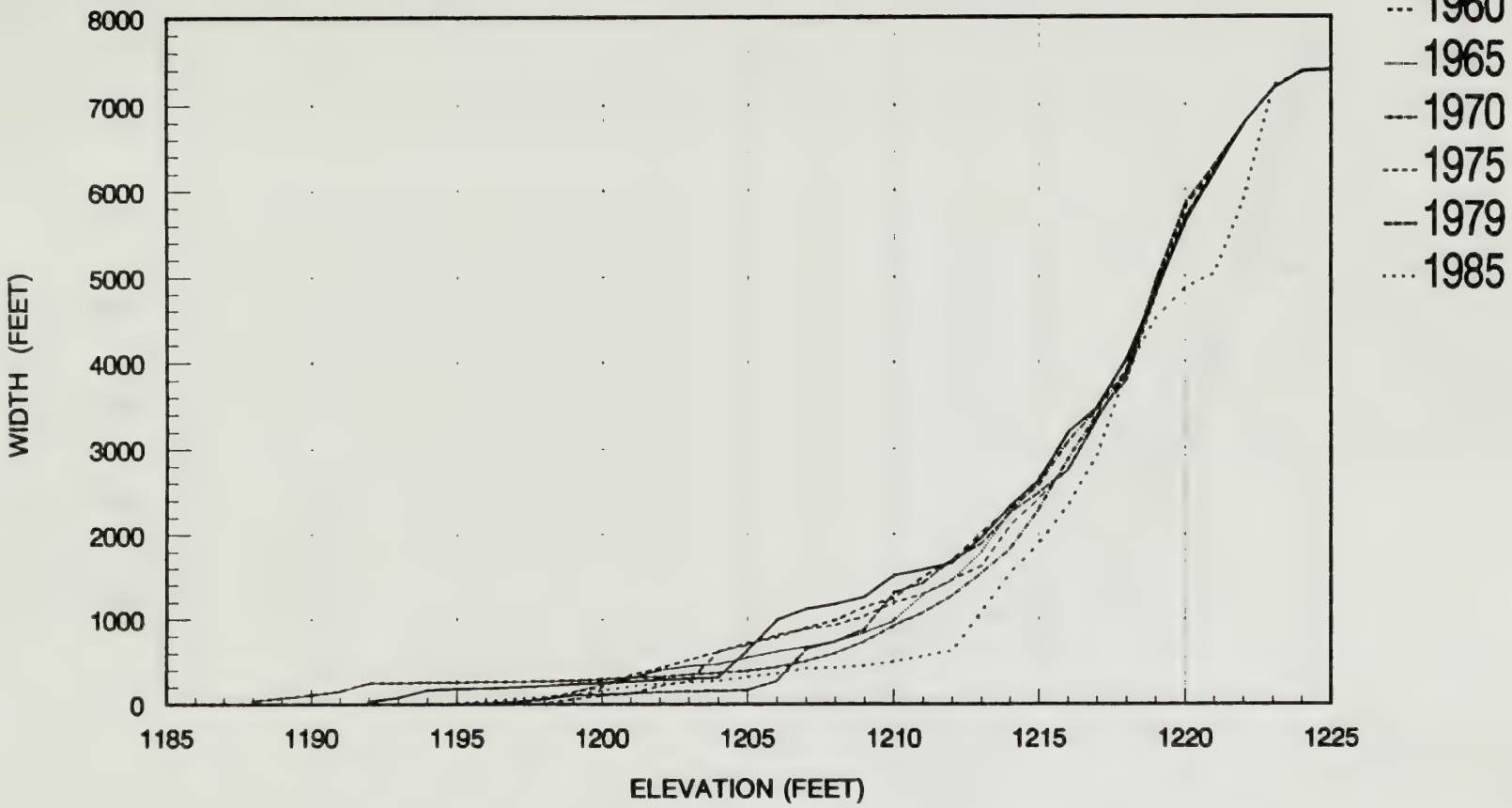


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION
(1960 RIVERMILE 844.1)



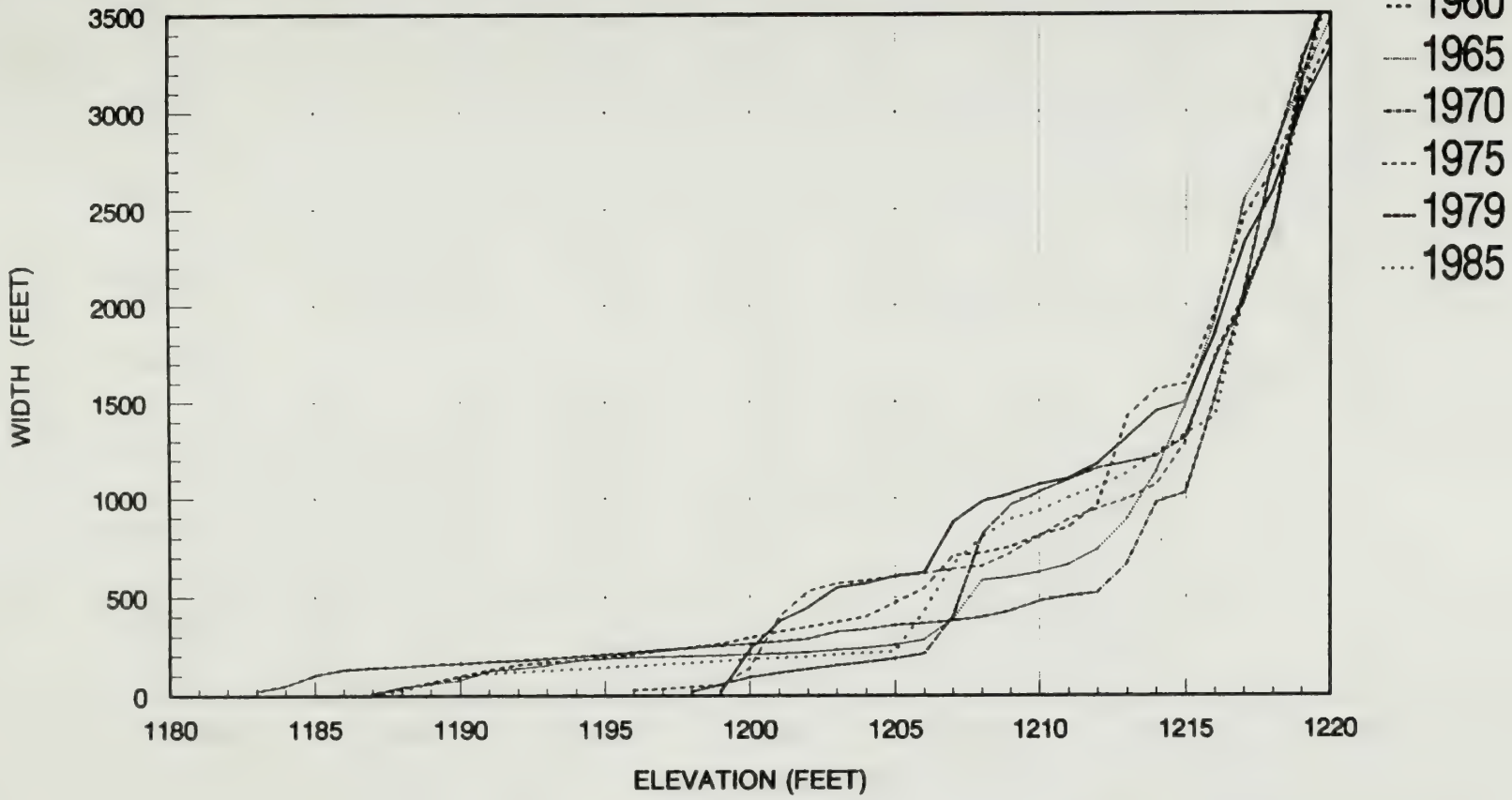
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 838.5

CHANNEL WIDTH (W) AT GIVEN ELEVATION
(1960 RIVERMILE 845.2)

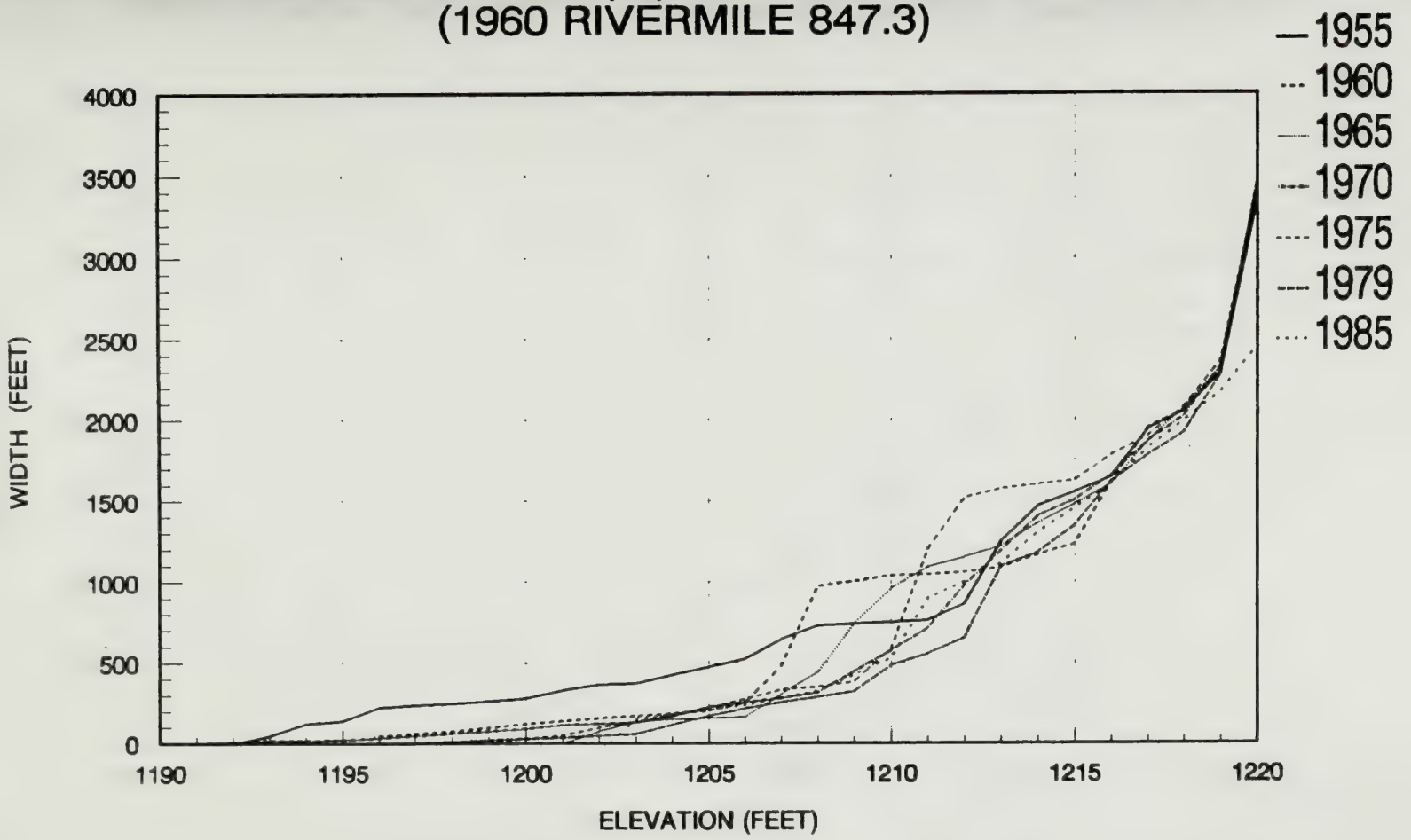


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CHANNEL WIDTH (W) AT GIVEN ELEVATION
(1960 RIVERMILE 847.3)



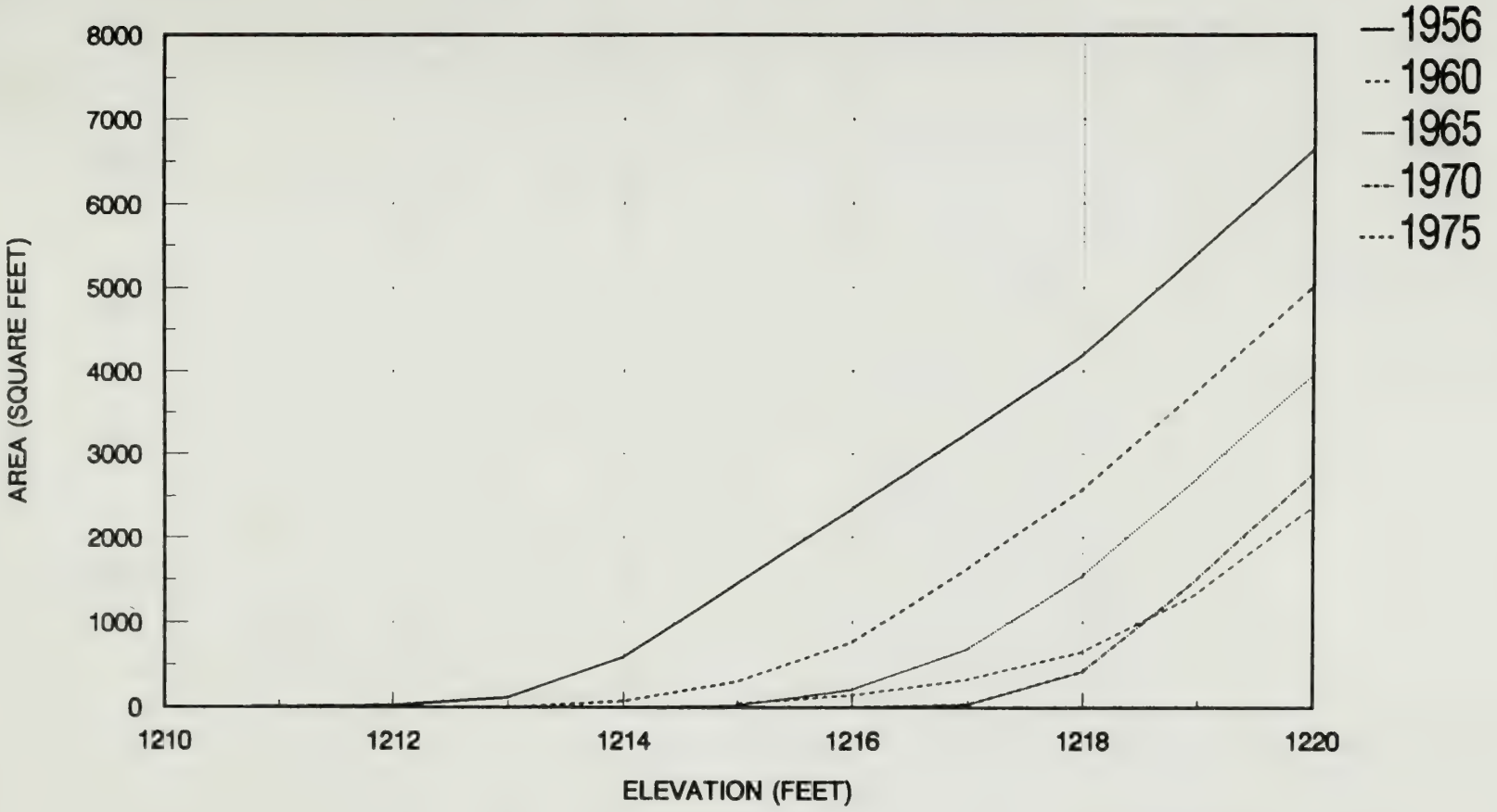
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 0.0

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

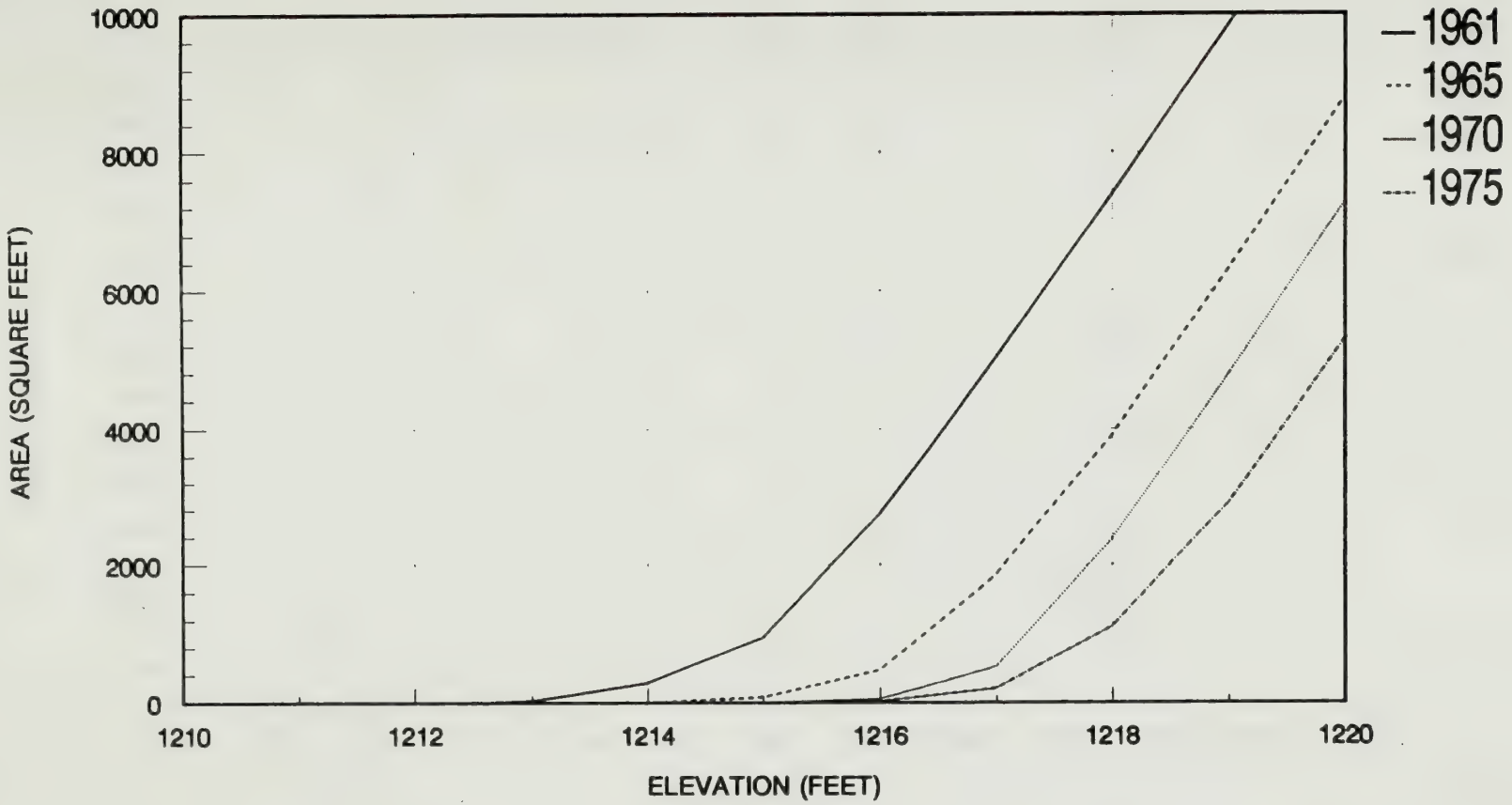


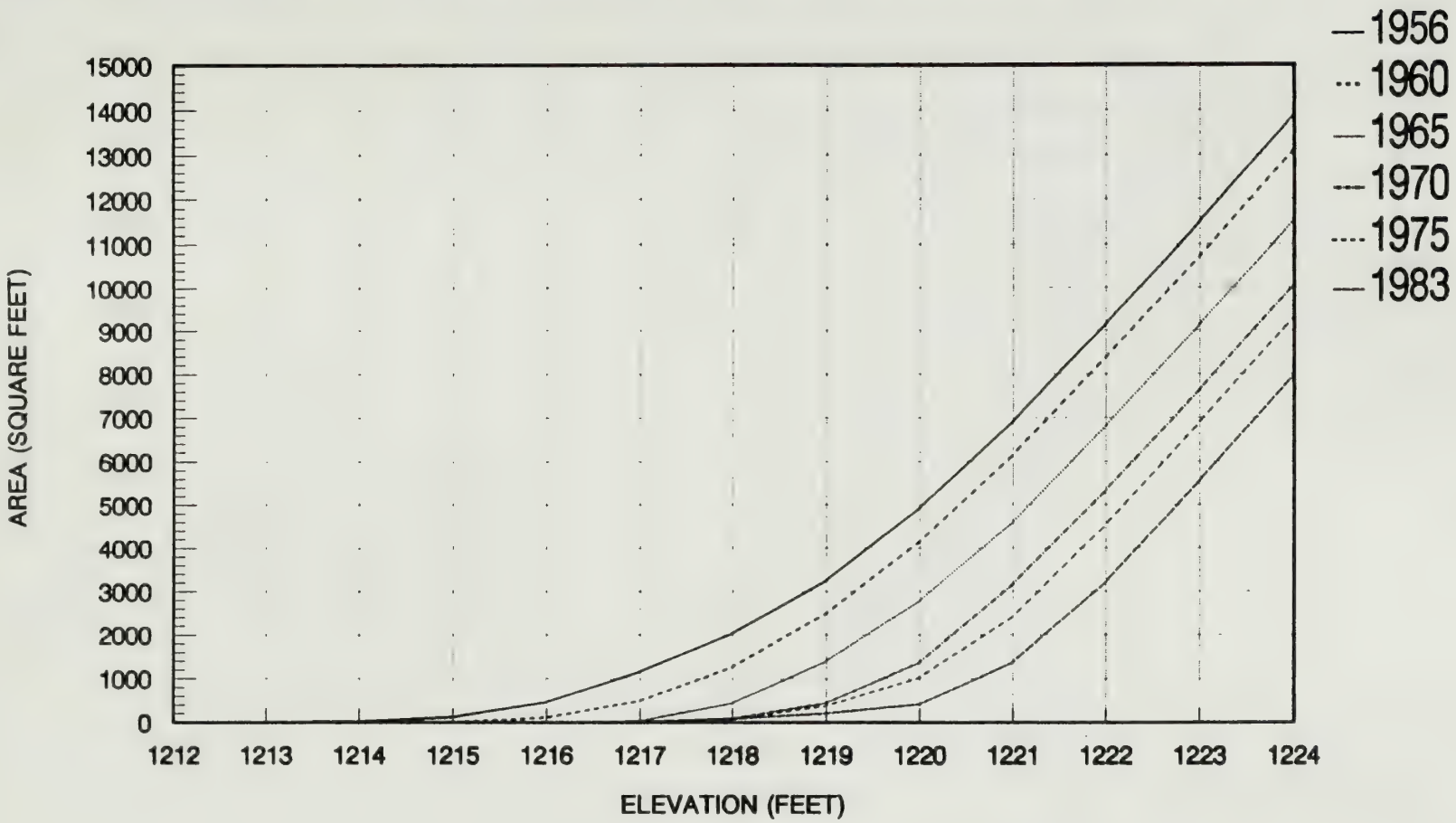
Plate IV.34

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

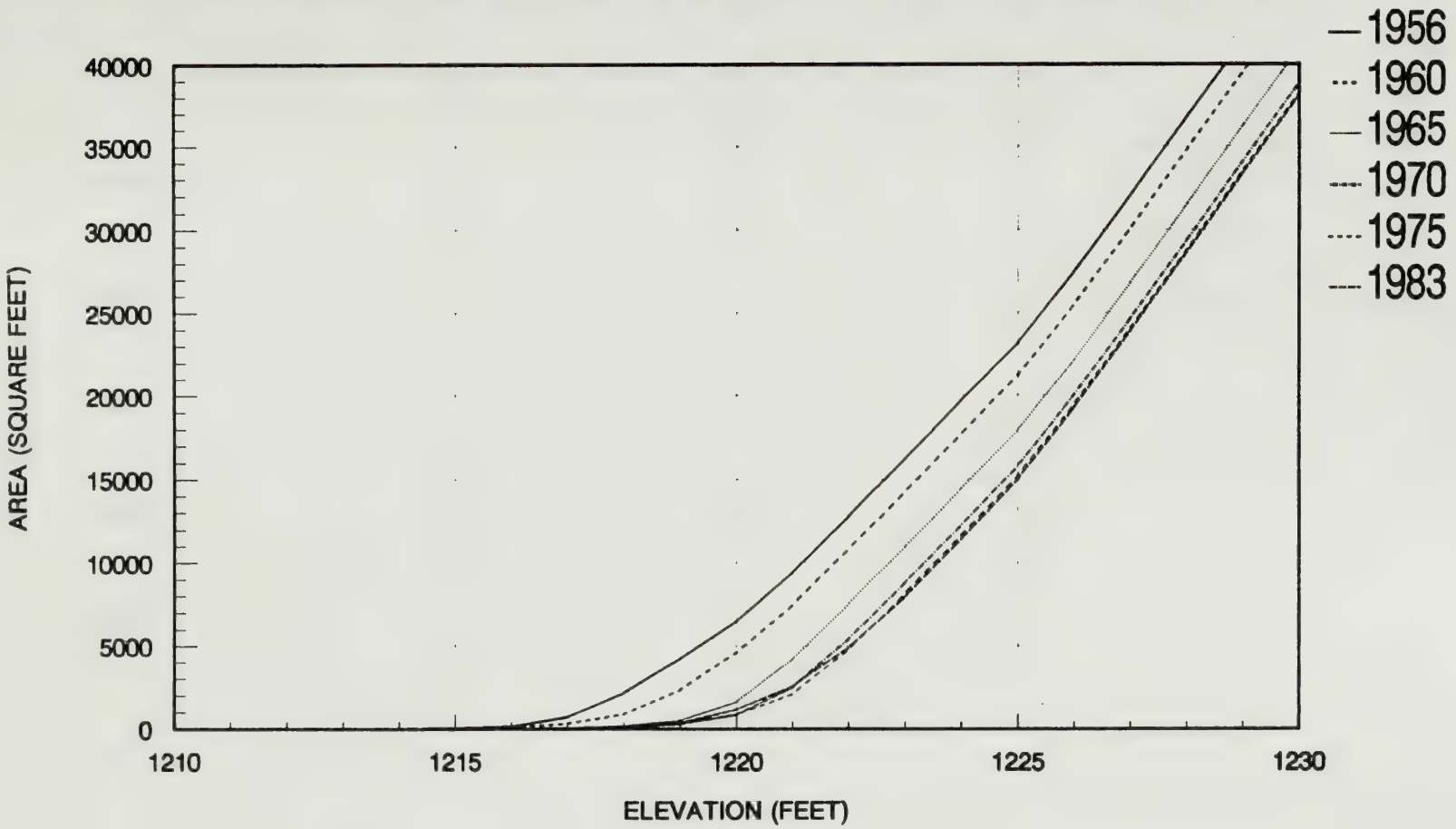


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

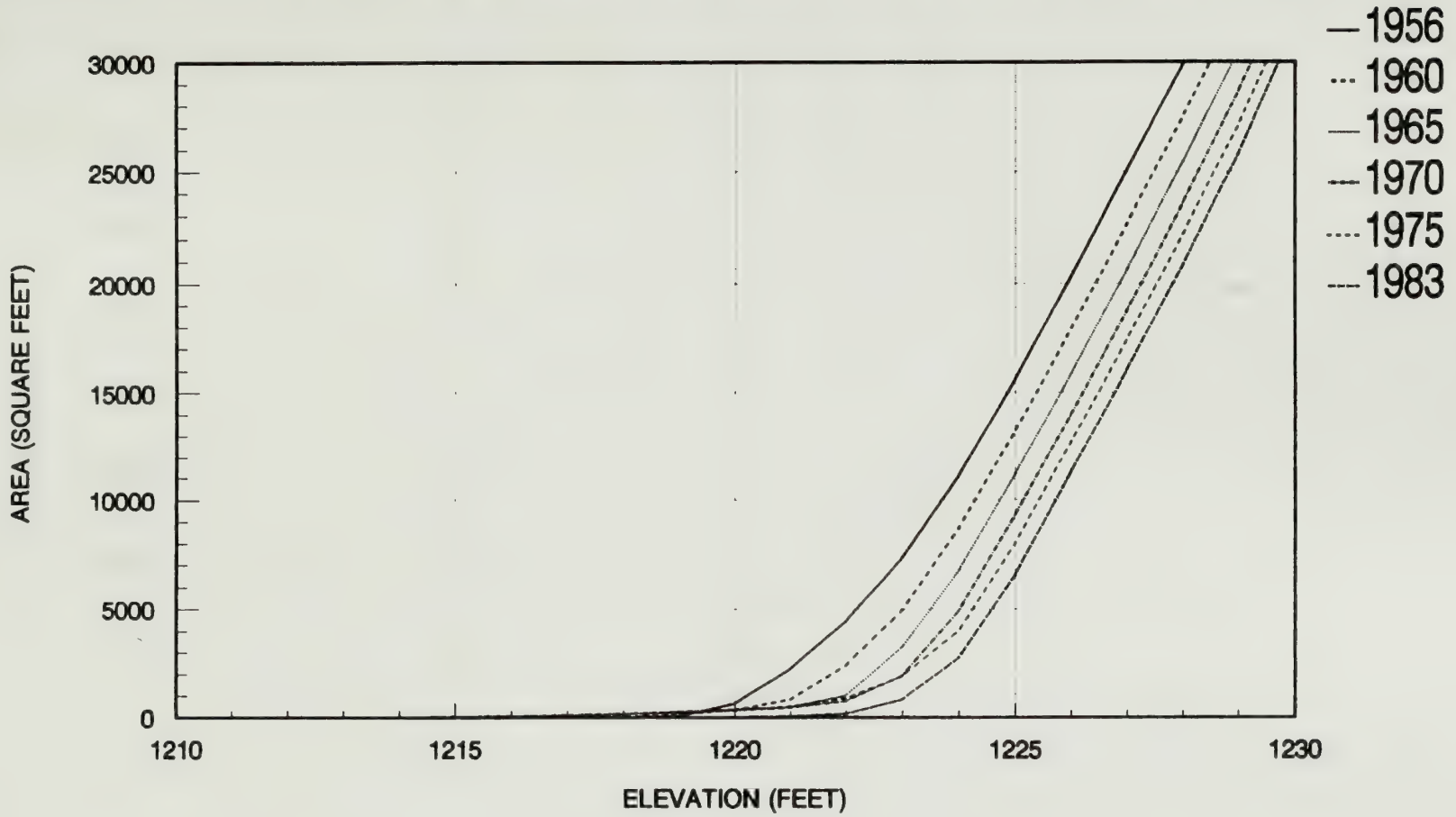


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

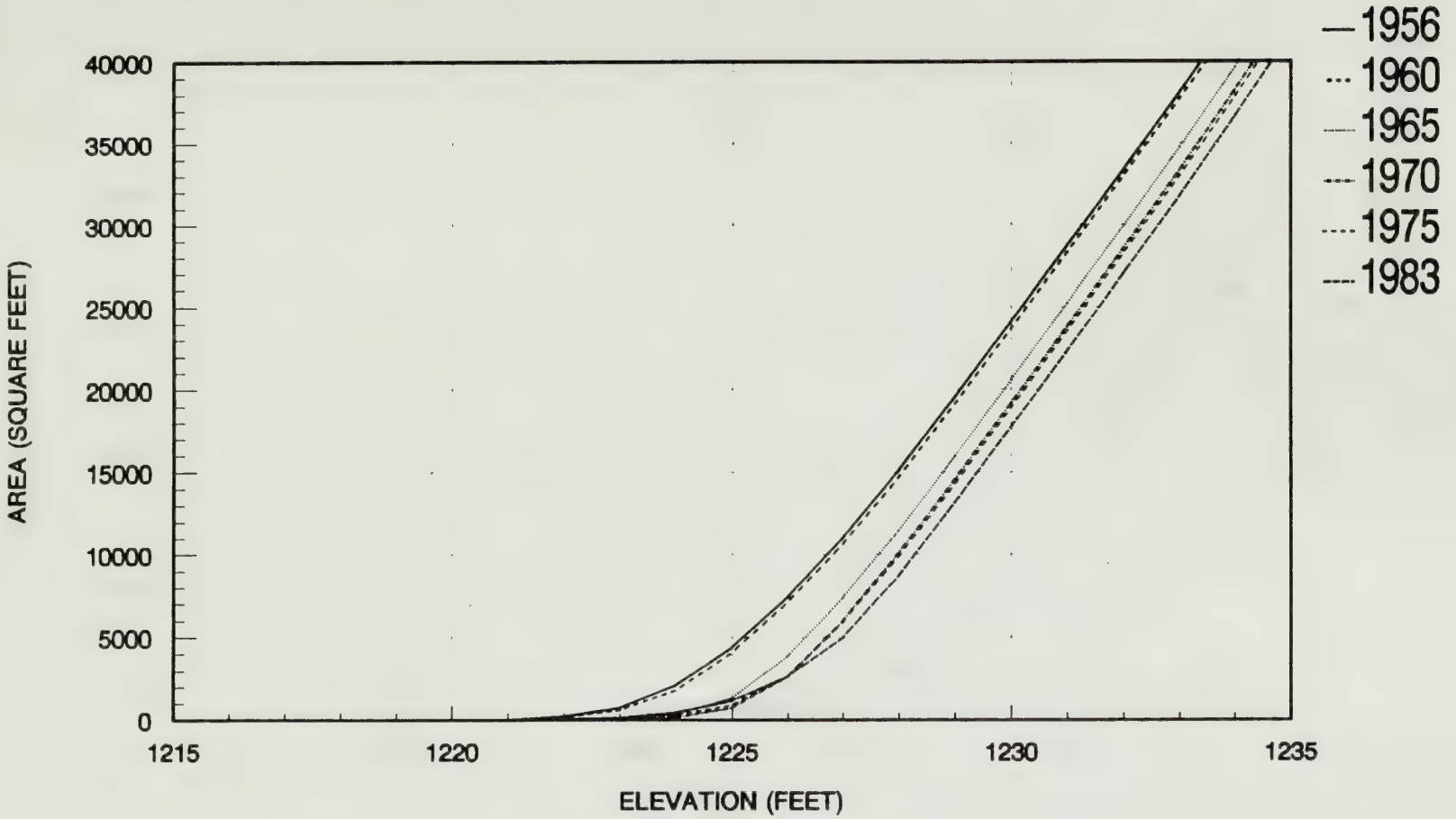


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

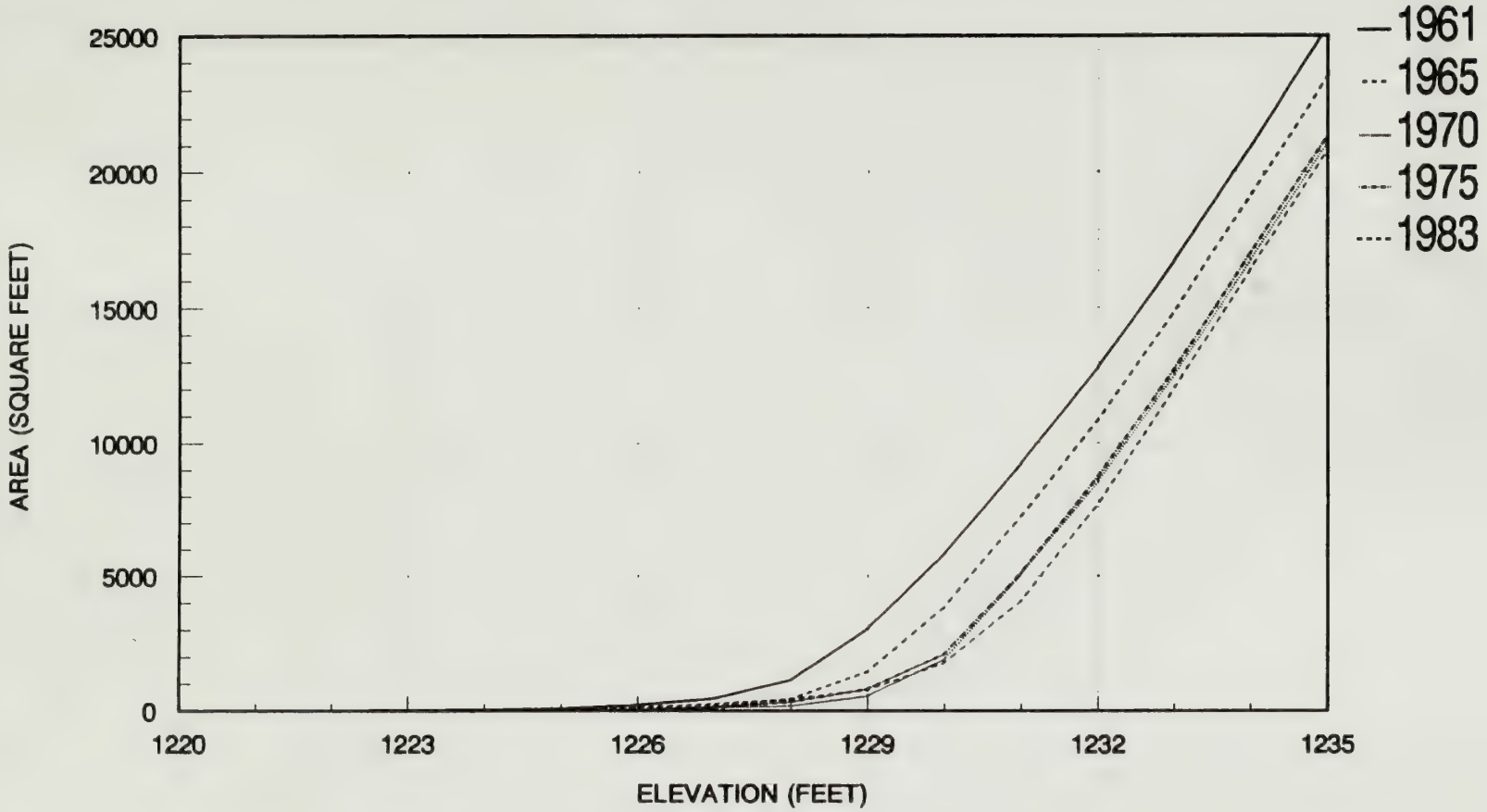


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

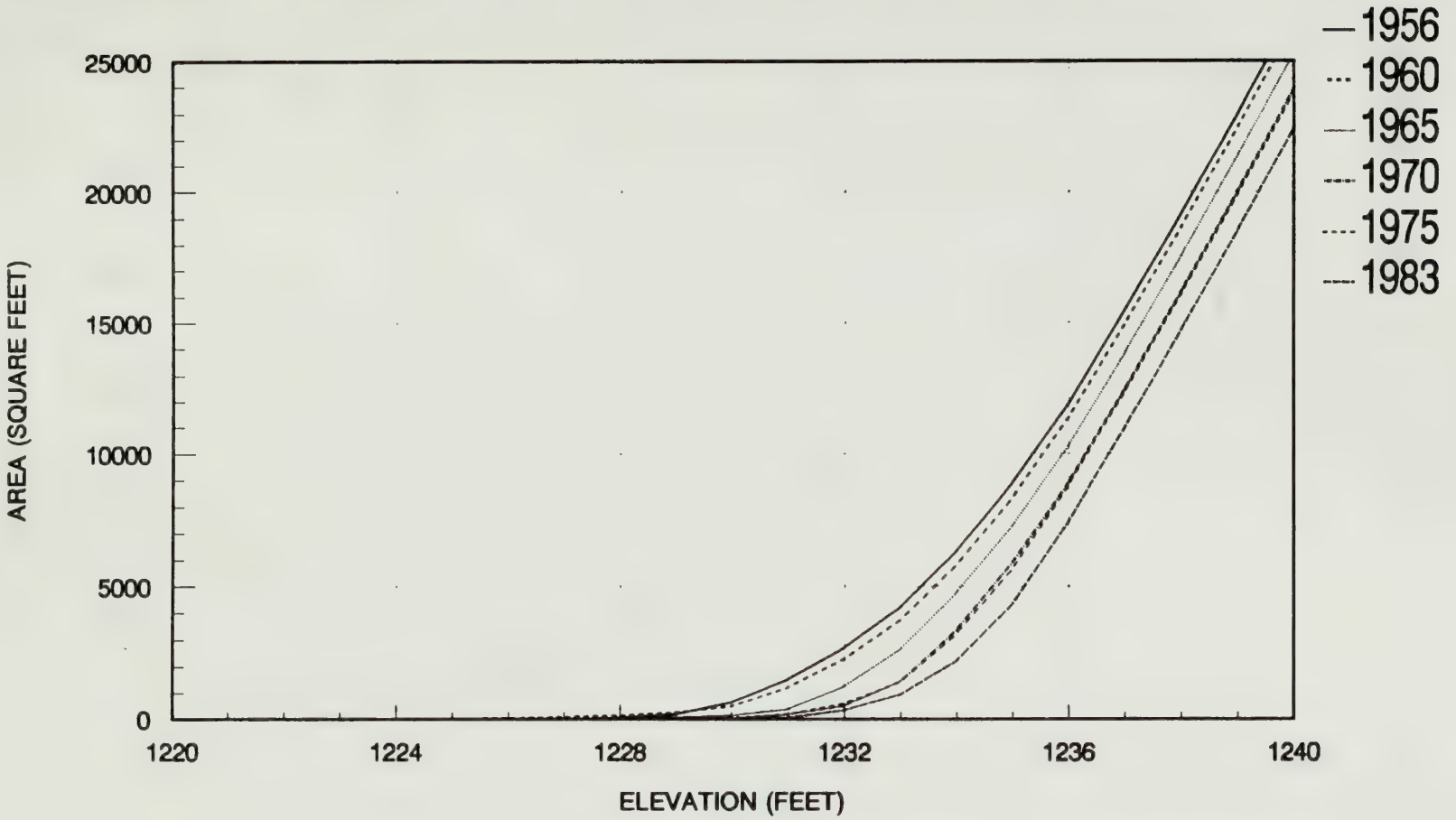


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

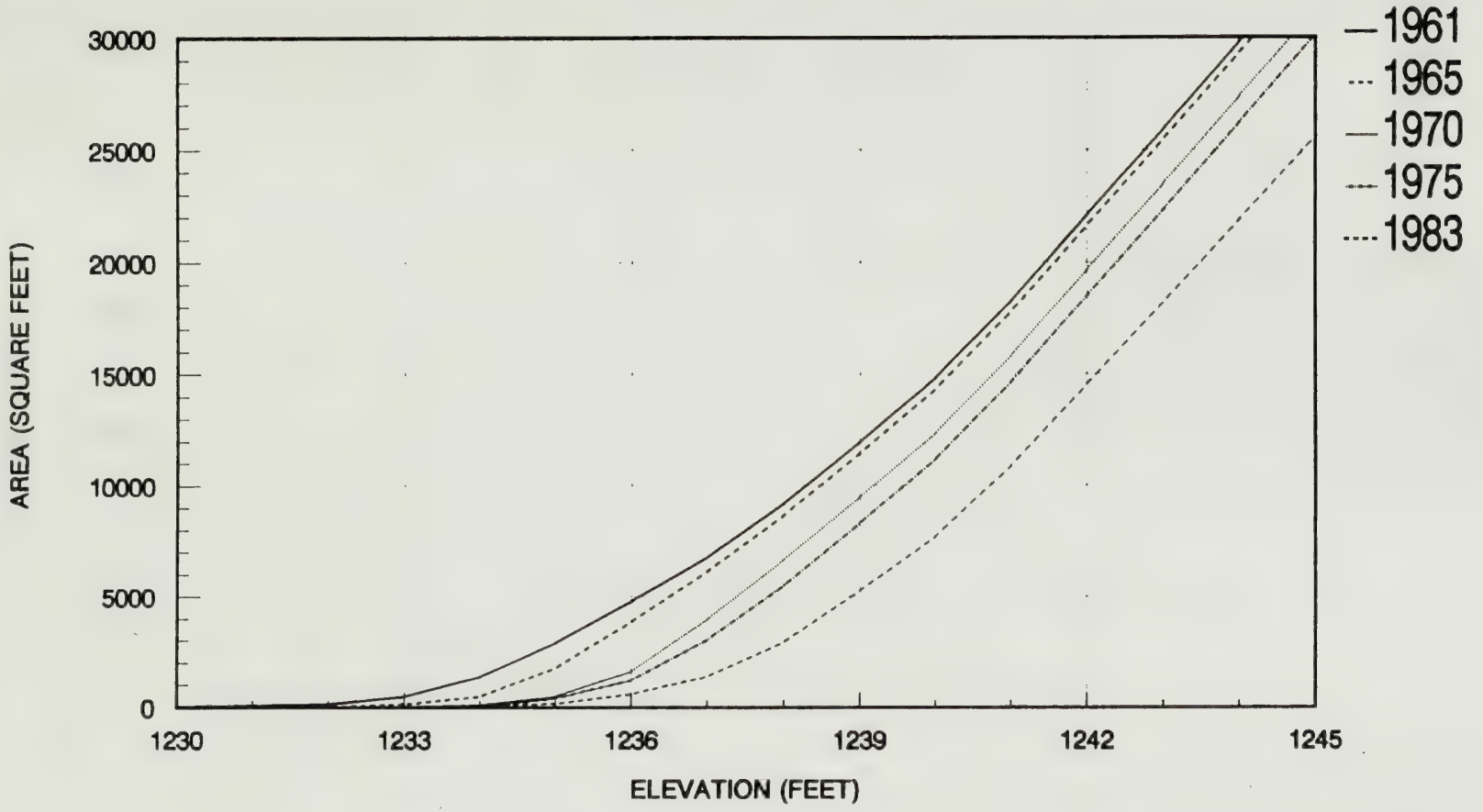


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

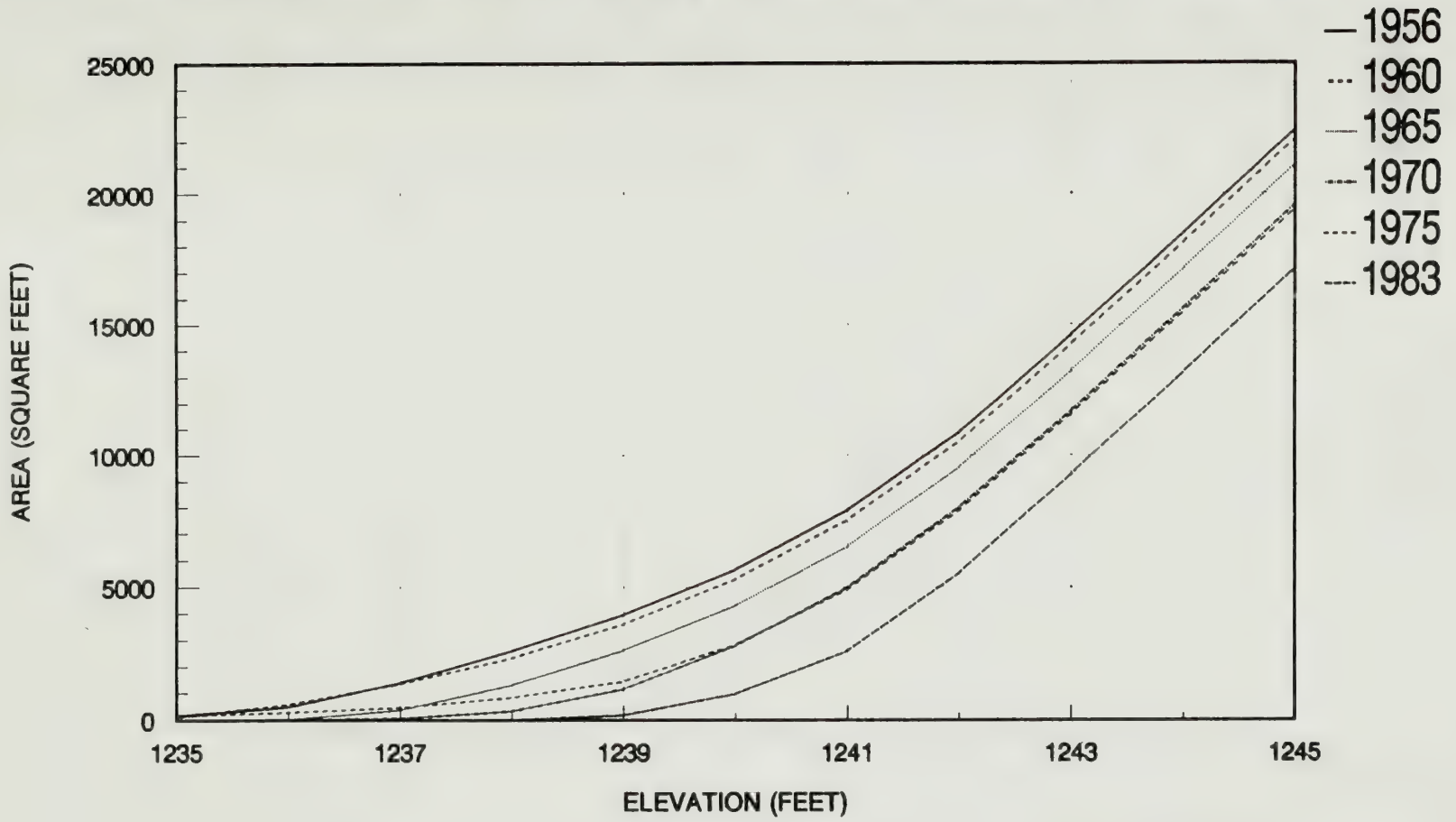


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 3.6
CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

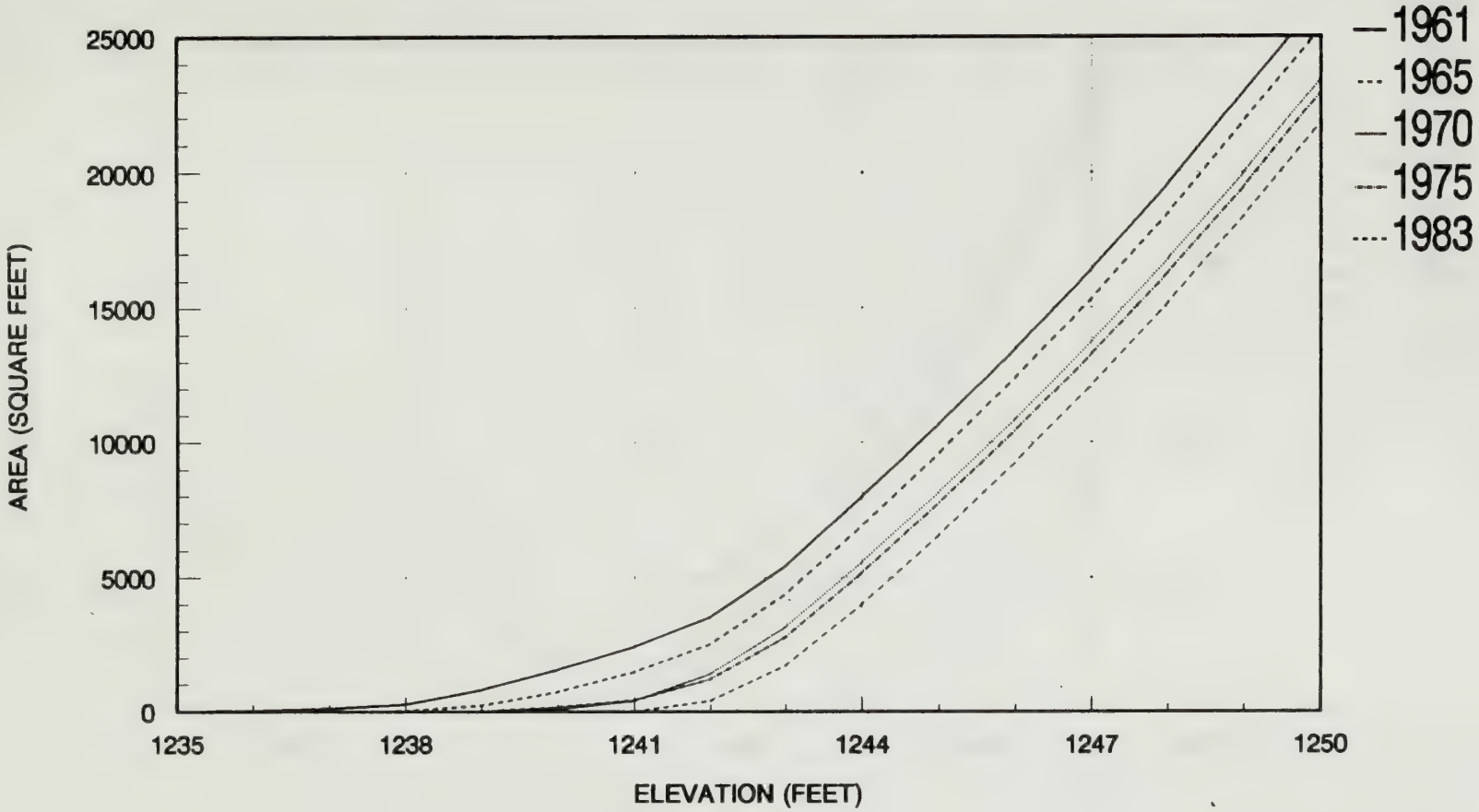


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION



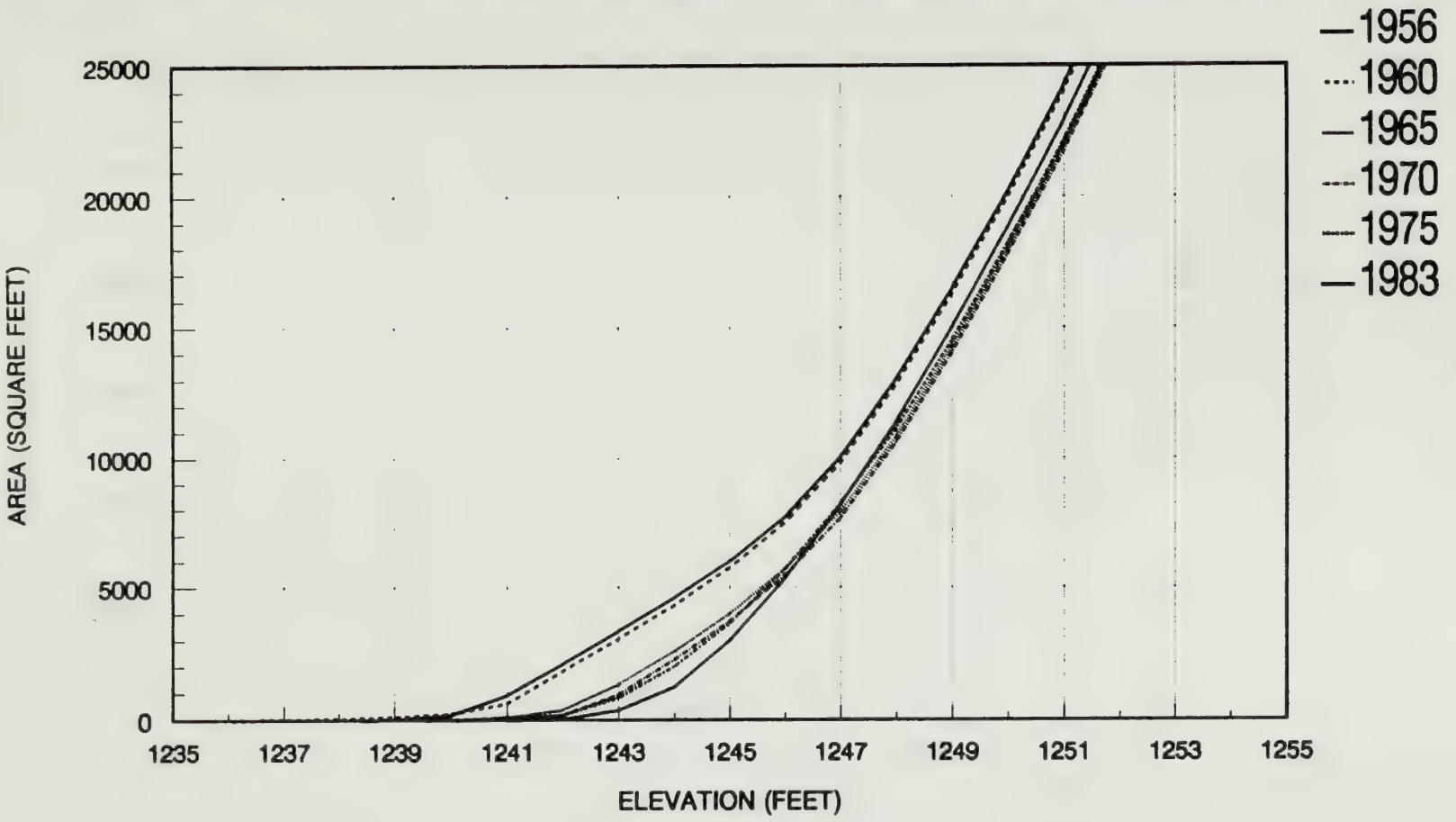
NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 4.4

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

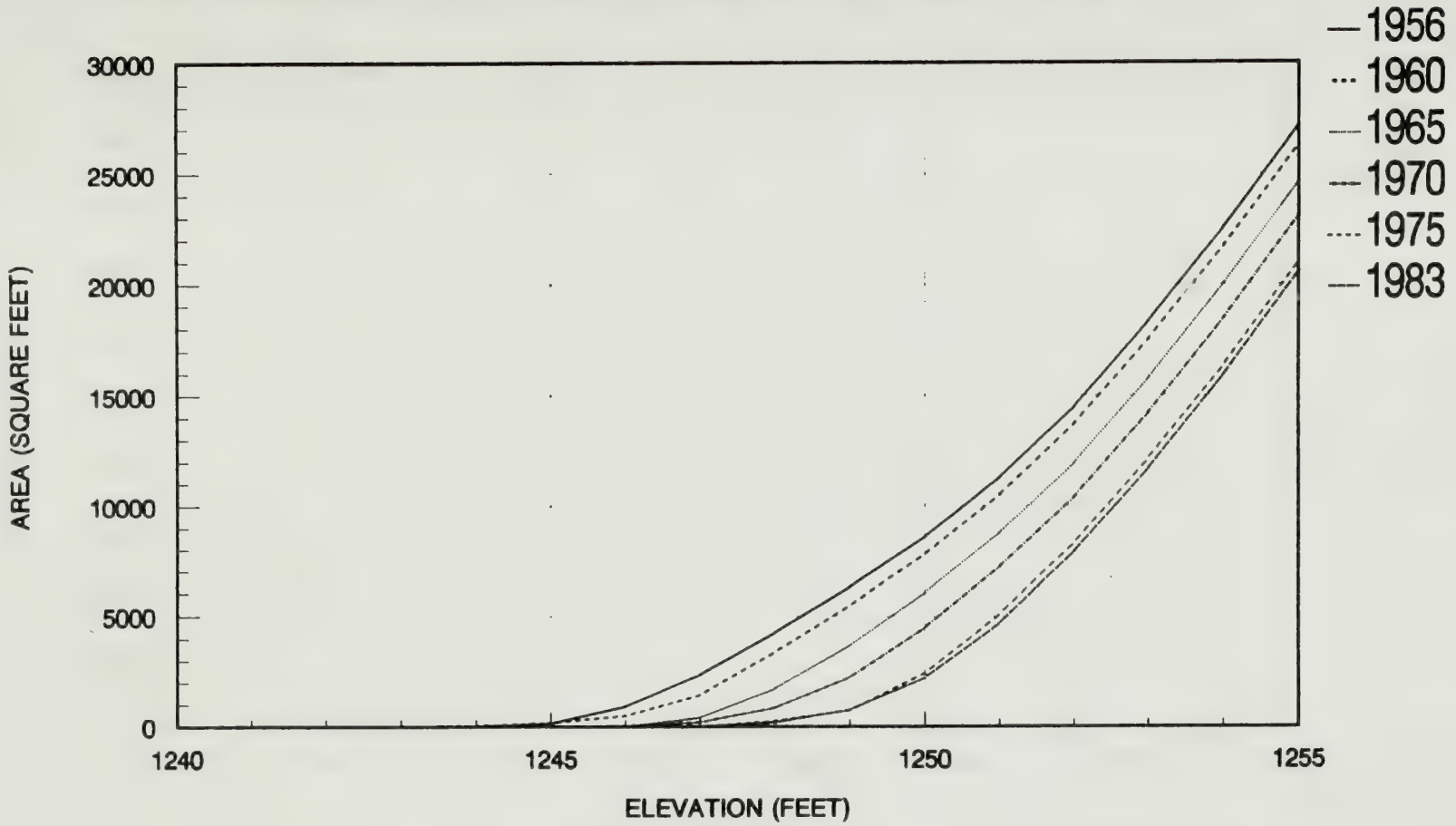


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

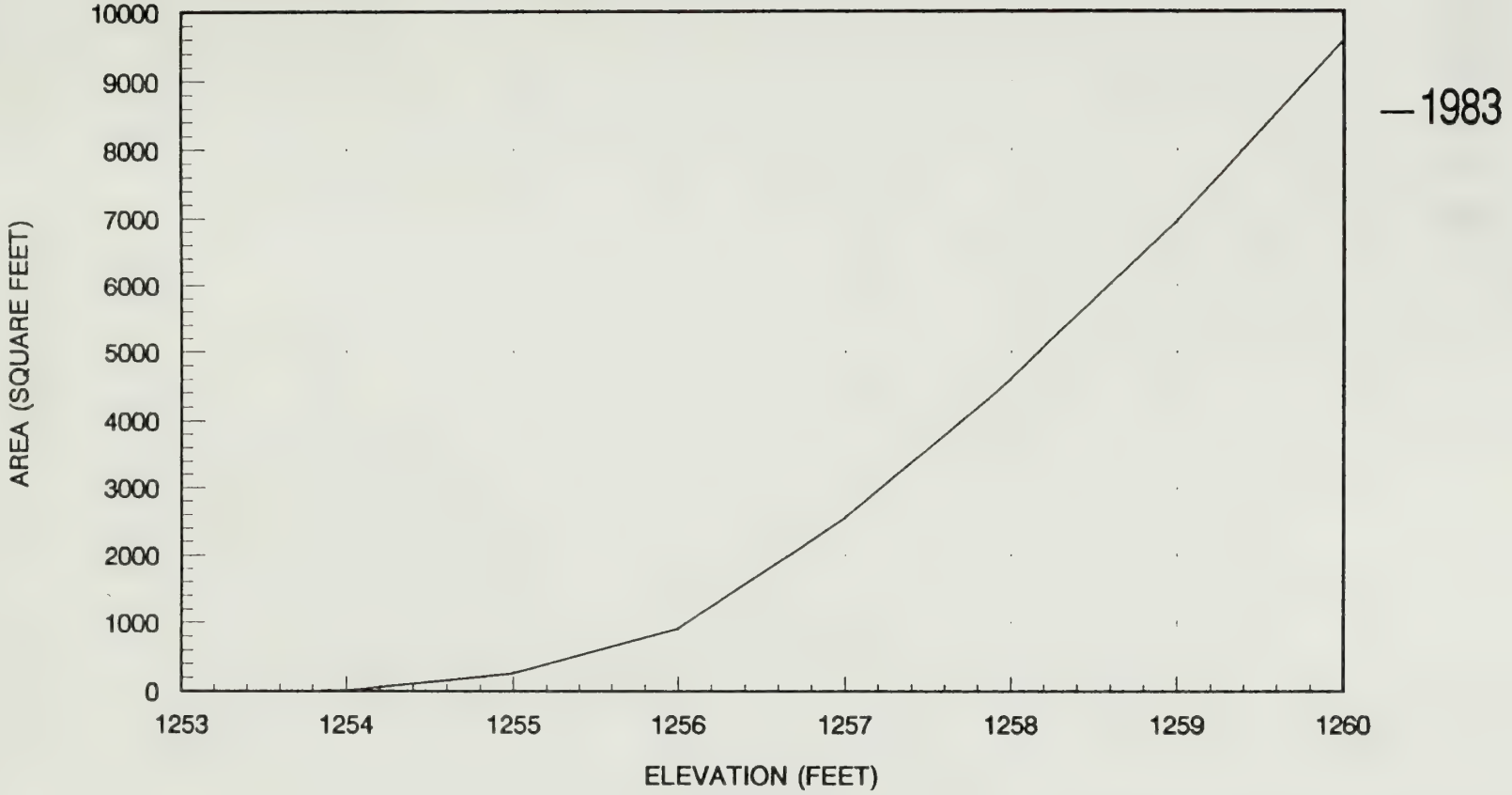


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 6.0
CROSS SECTION AREA (A) BELOW GIVEN ELEVATION



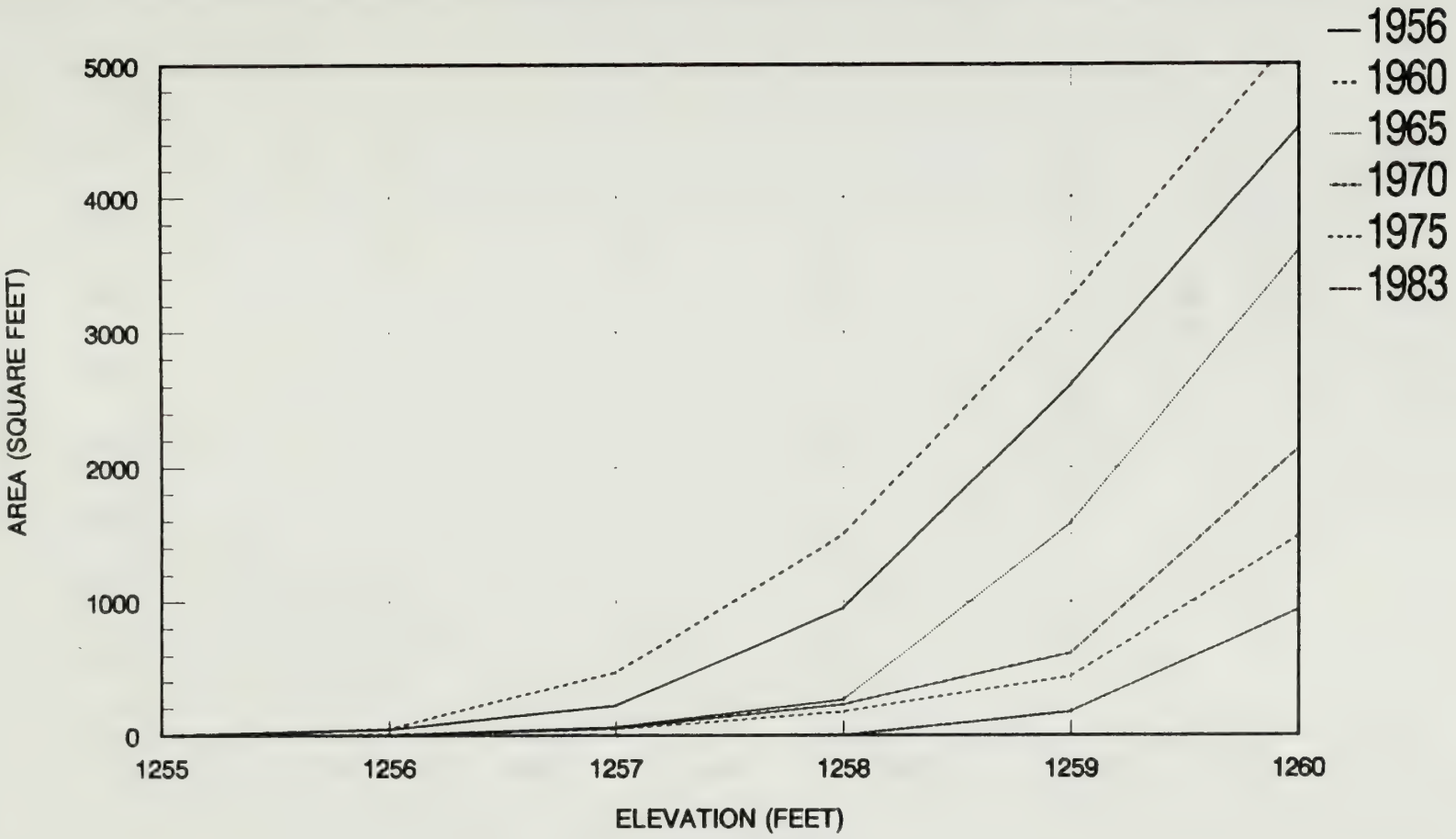
NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 6.9

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

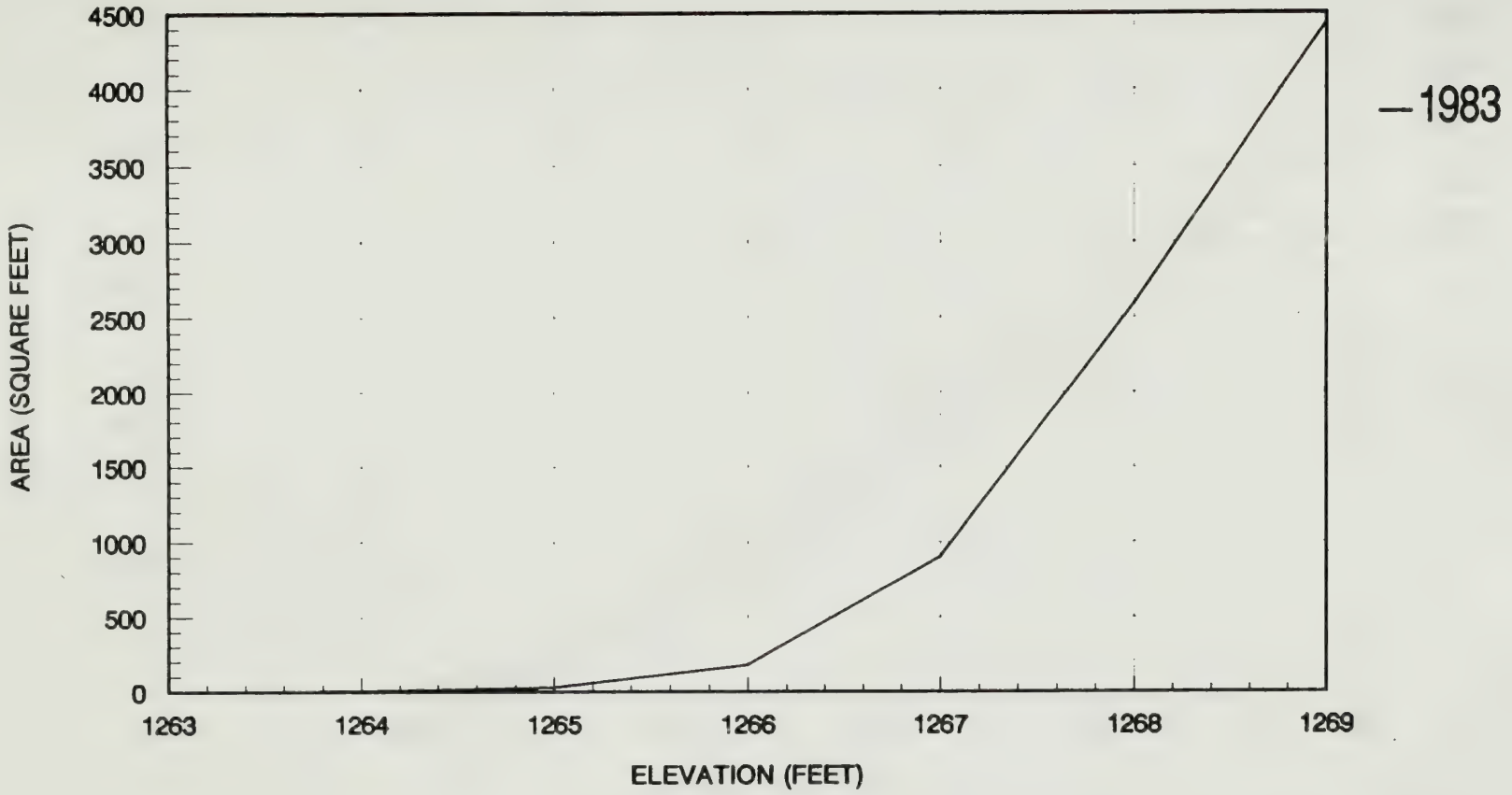


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 8.0
CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

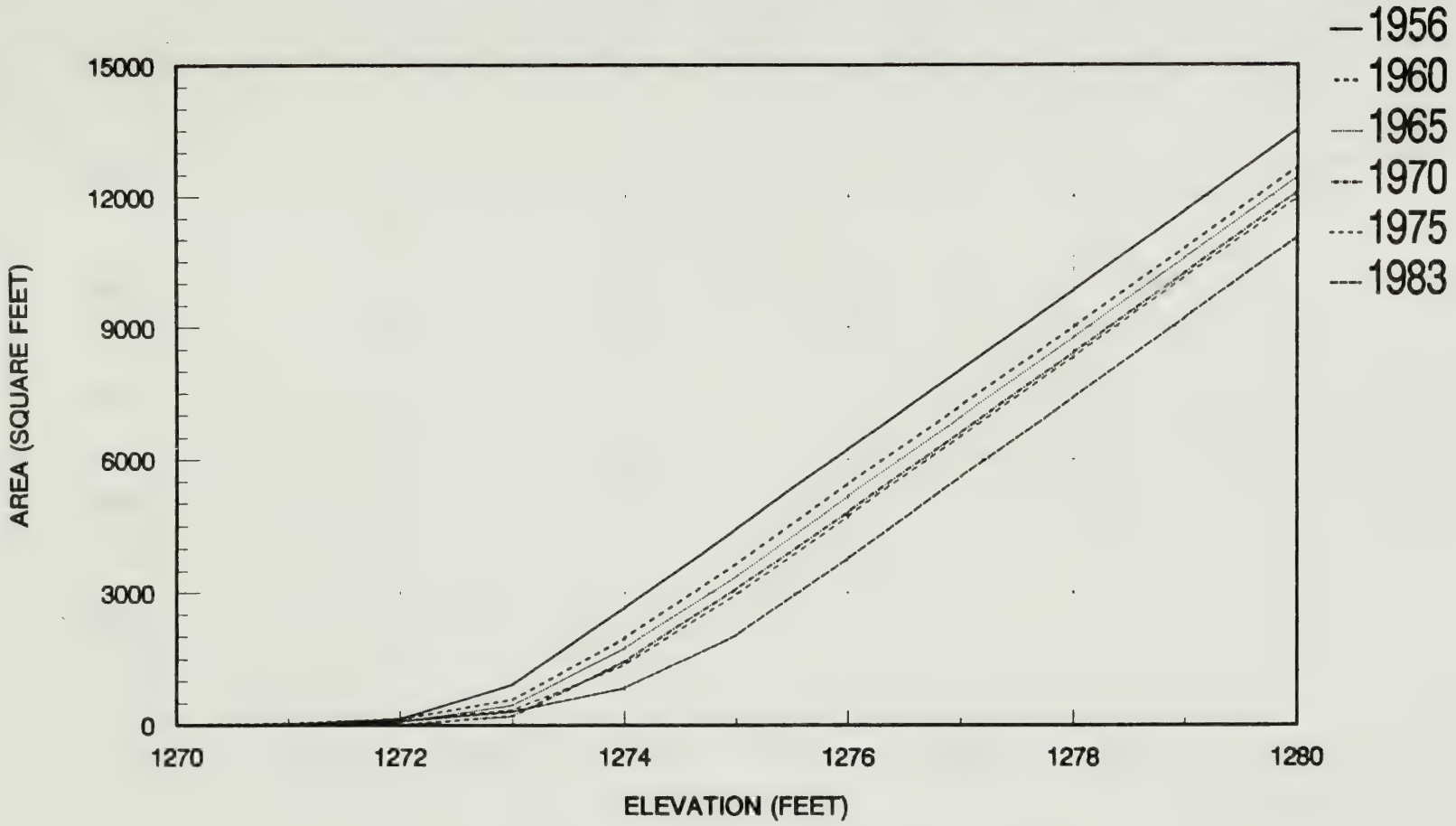


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 9.0
CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

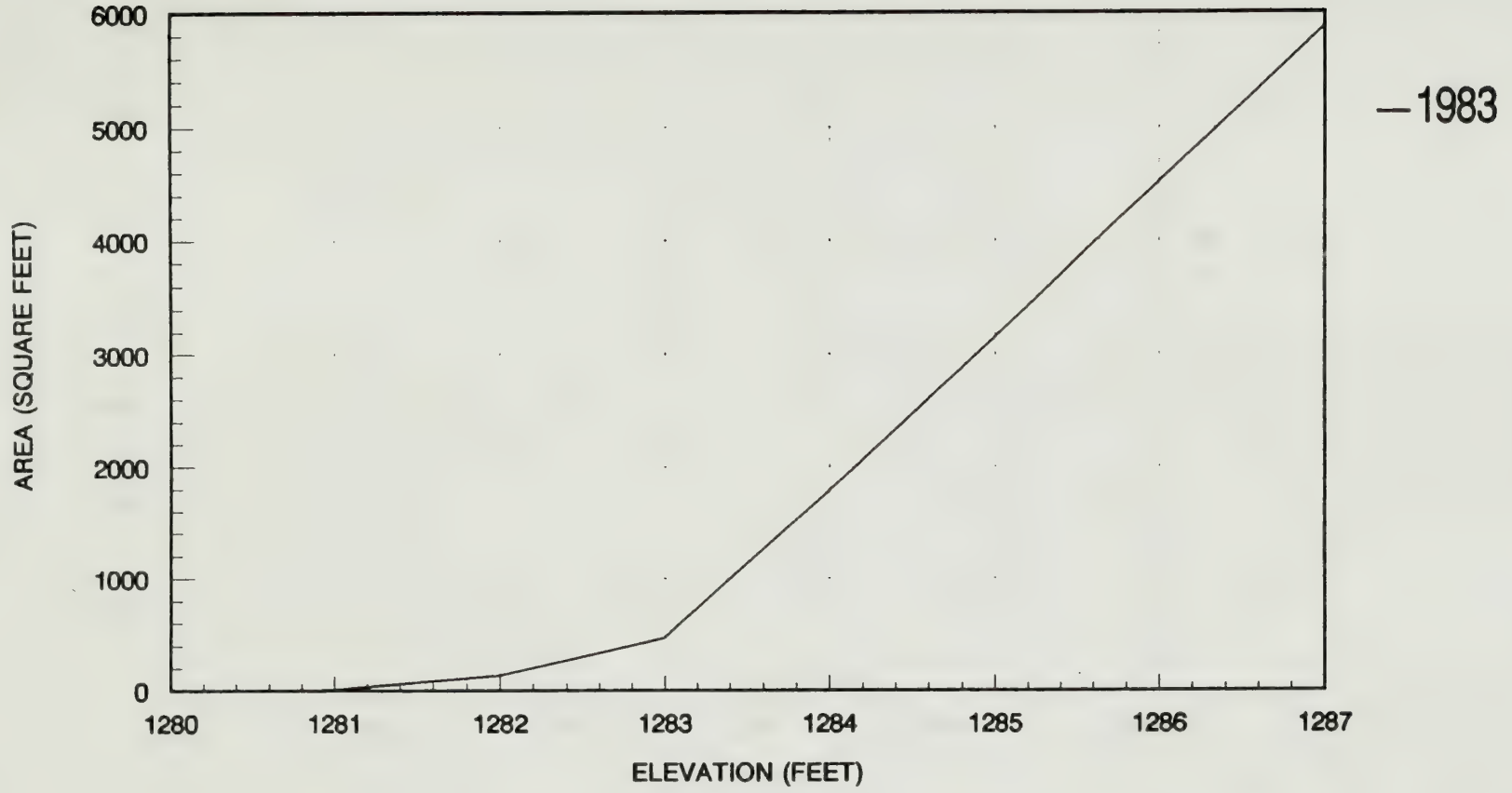


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N10.5
CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

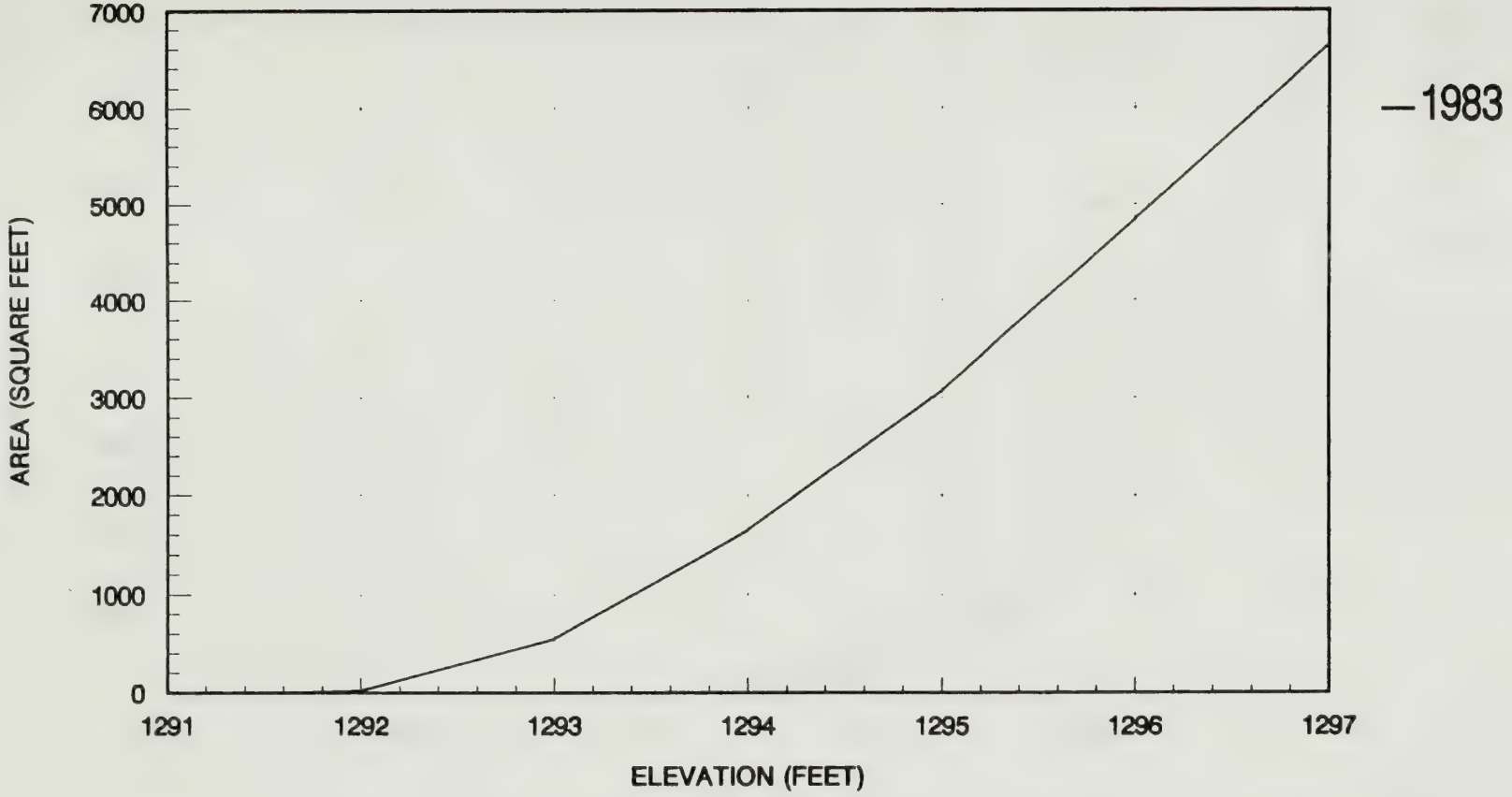


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N11.6
CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

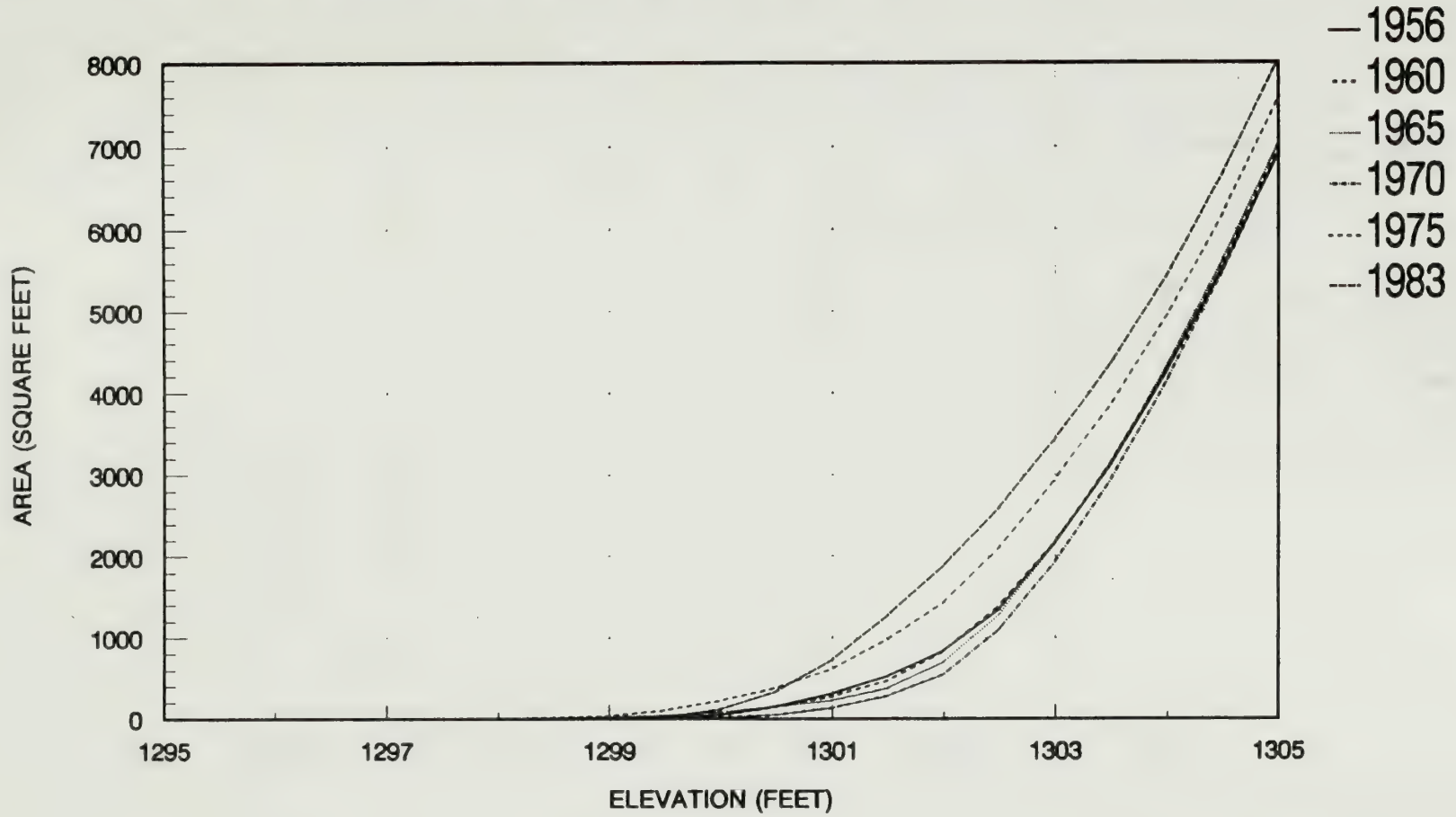


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N13.0
CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

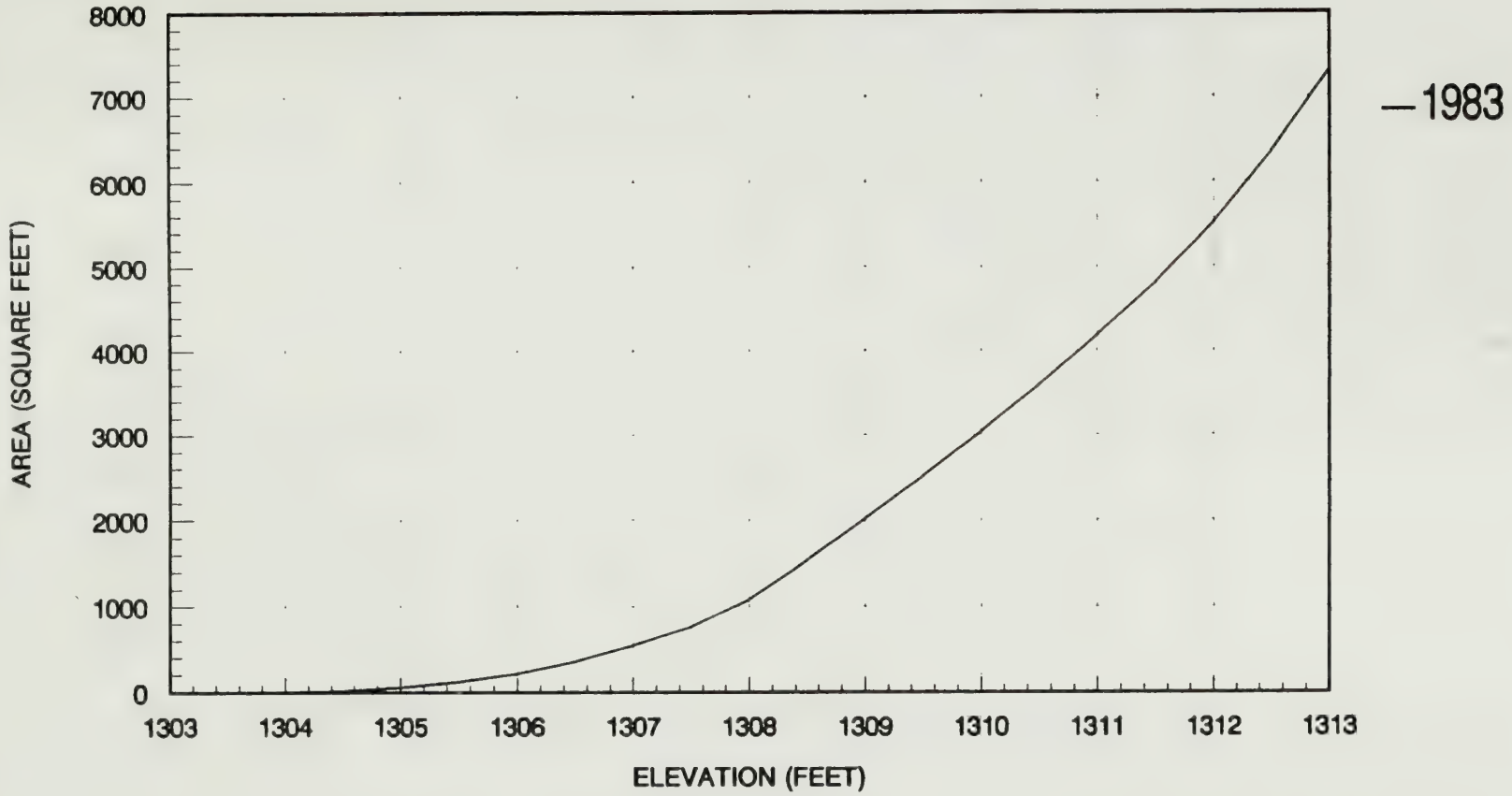


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 13.8
CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

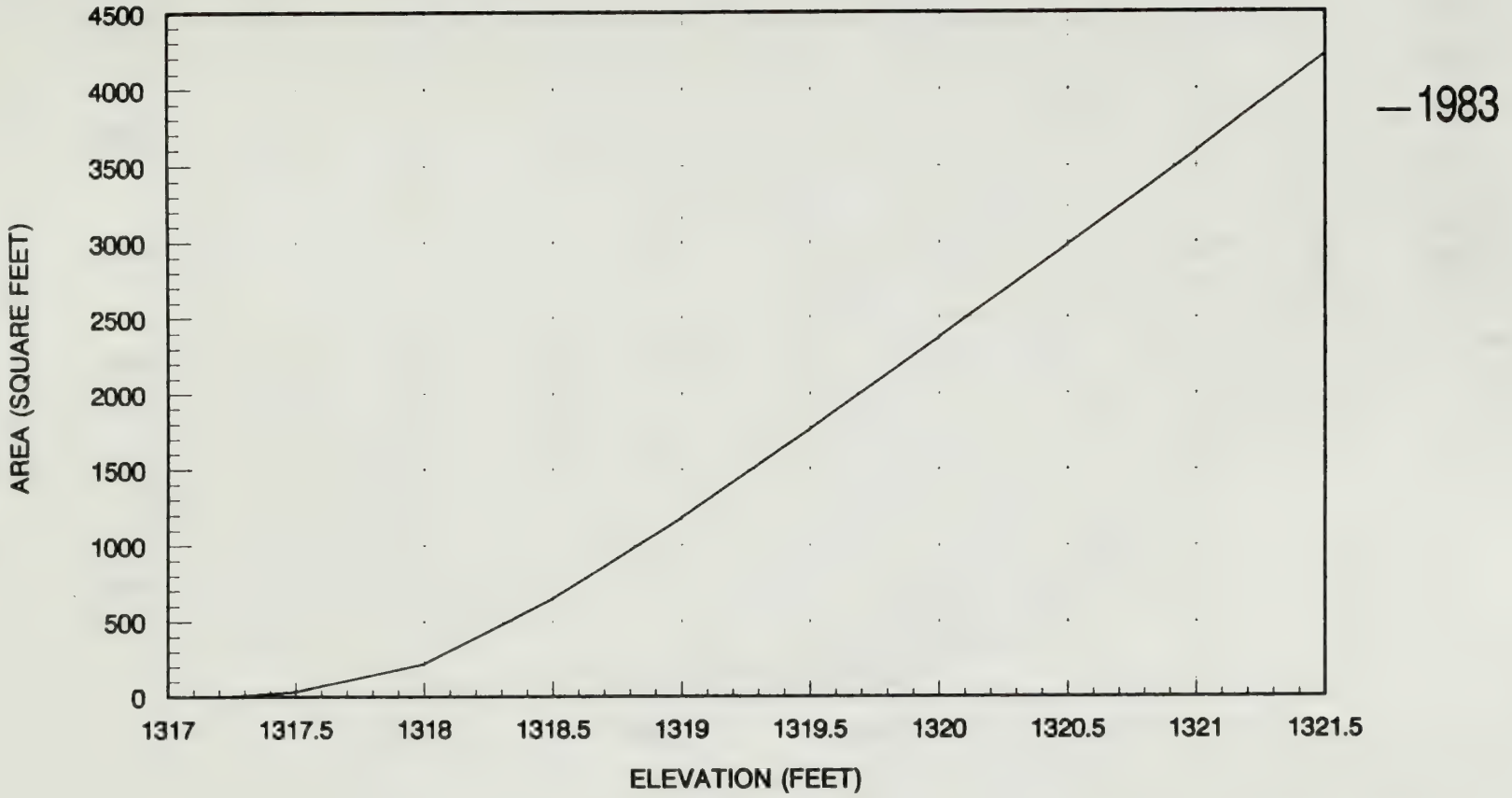


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N14.5
CROSS SECTION AREA (A) BELOW GIVEN ELEVATION

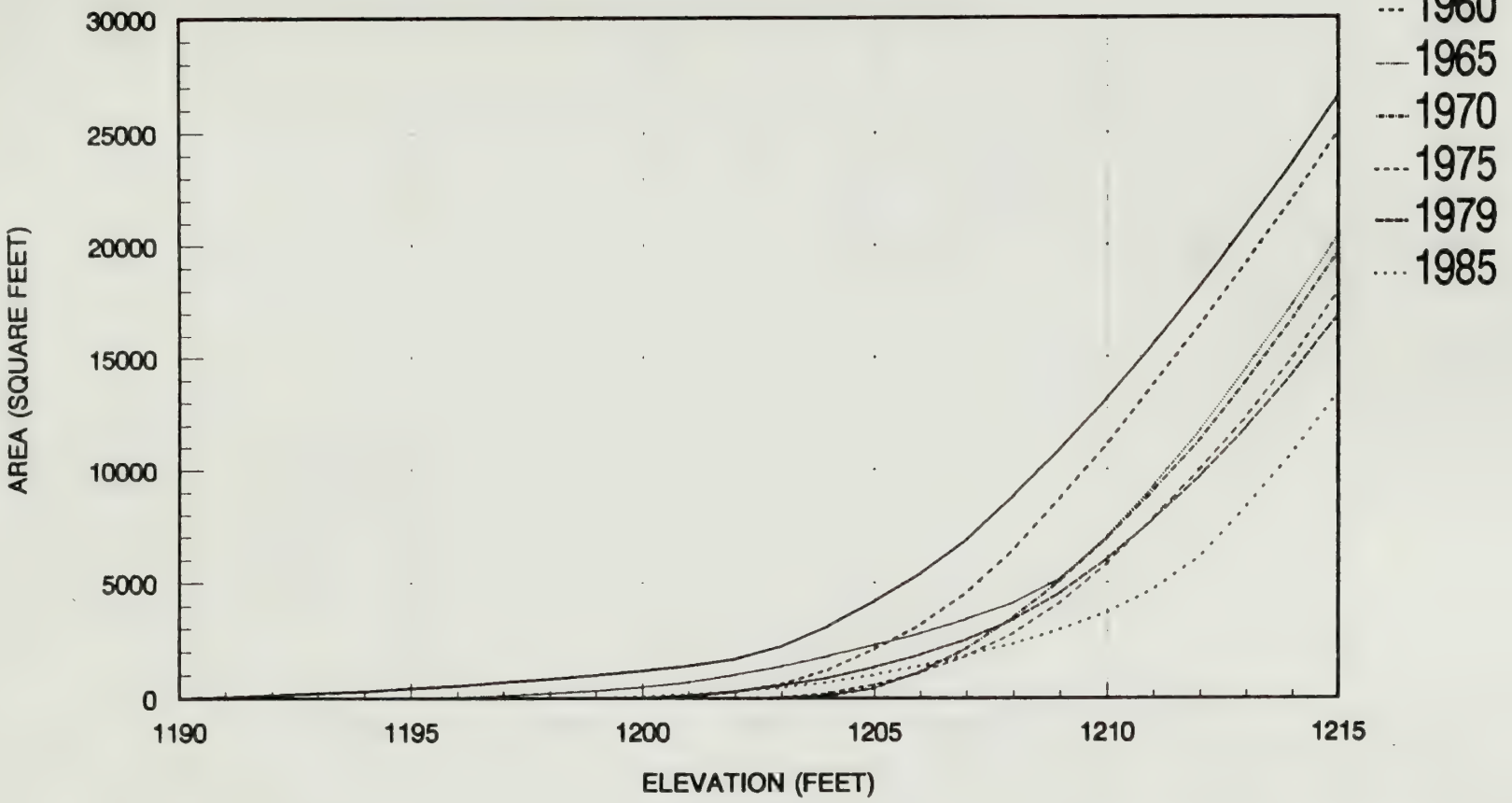


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 846.0)

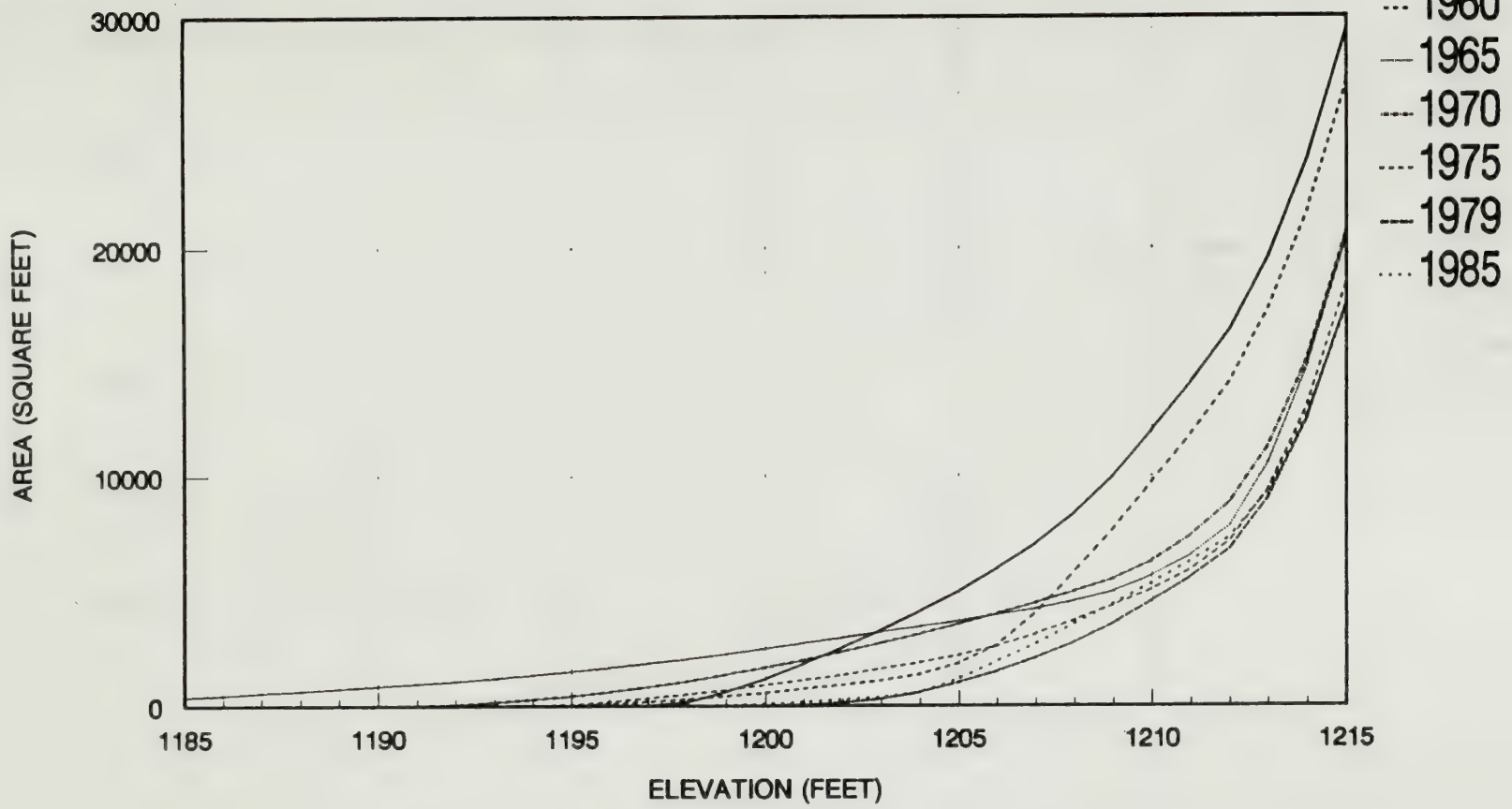


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 840.6)



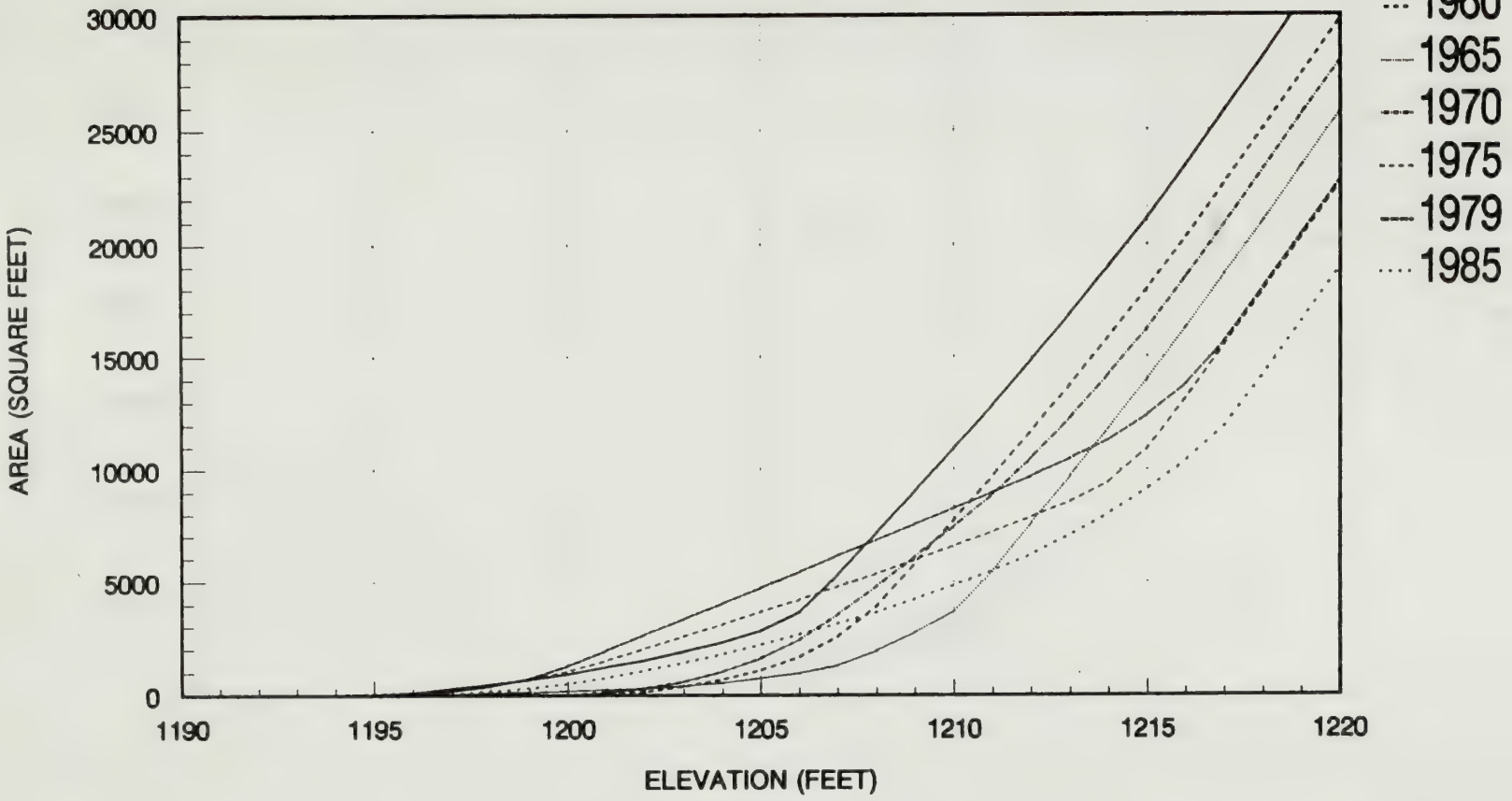
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 882.6

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 841.2)

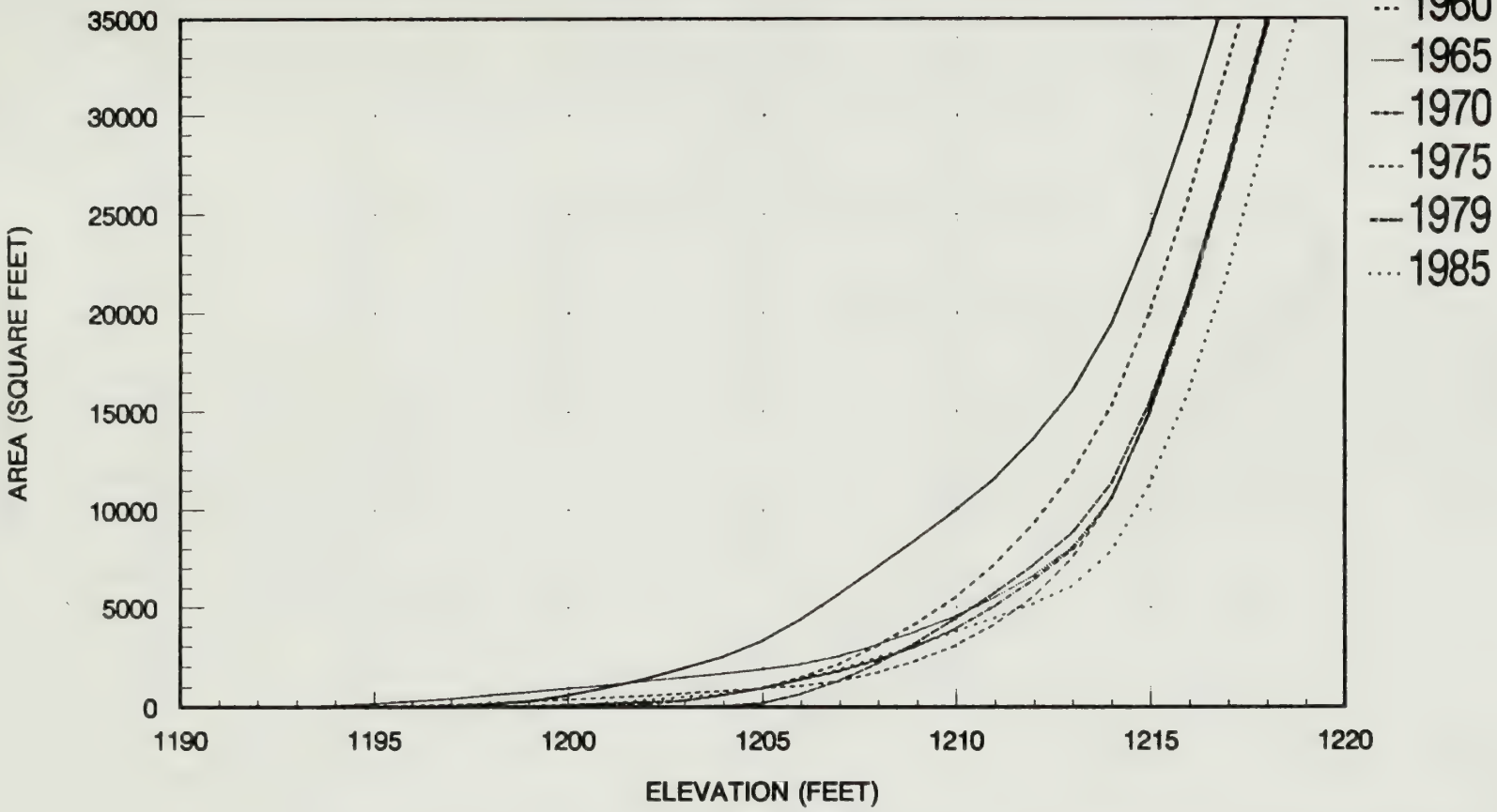


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 841.9)



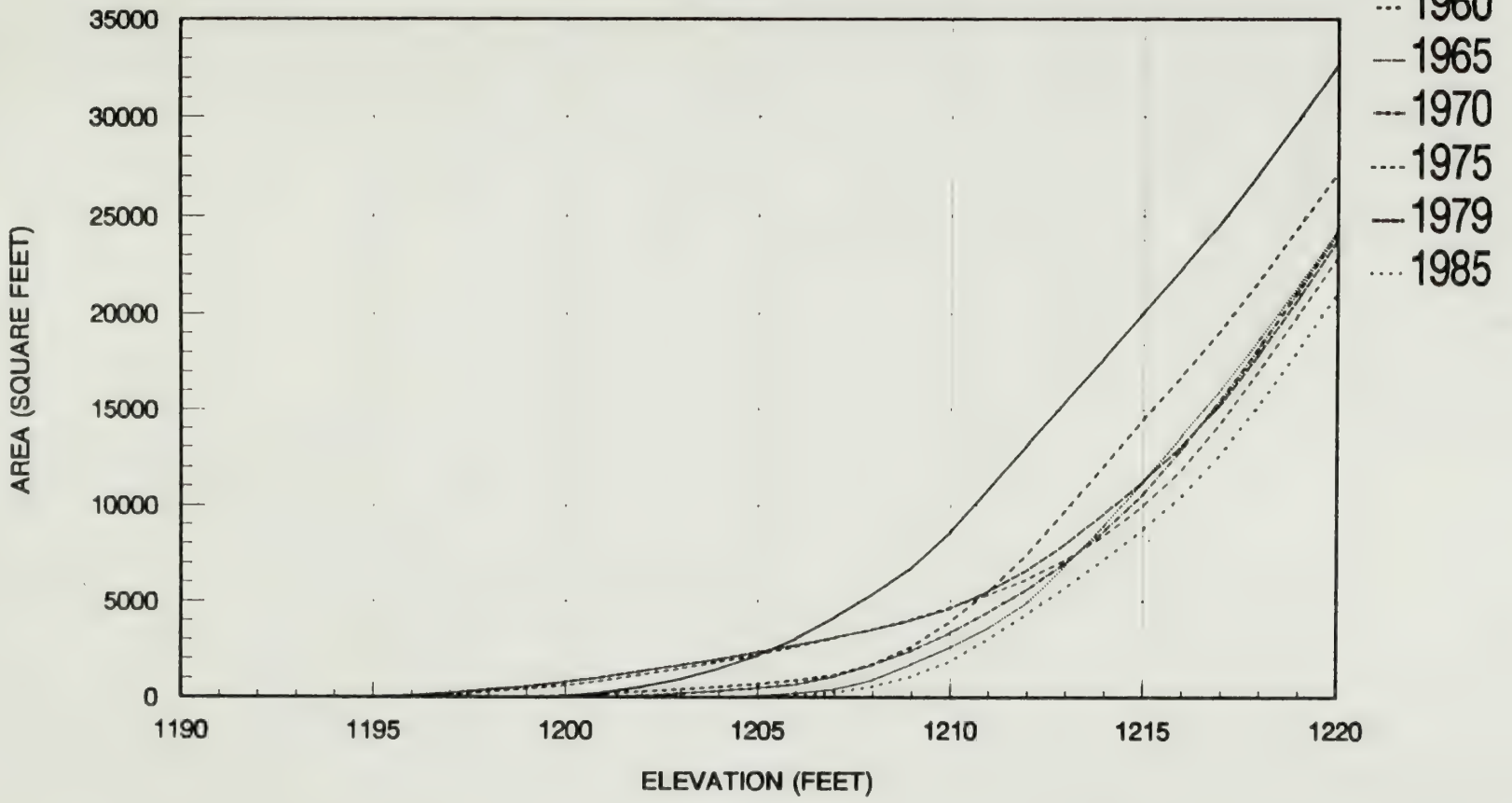
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 883.9

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 842.4)



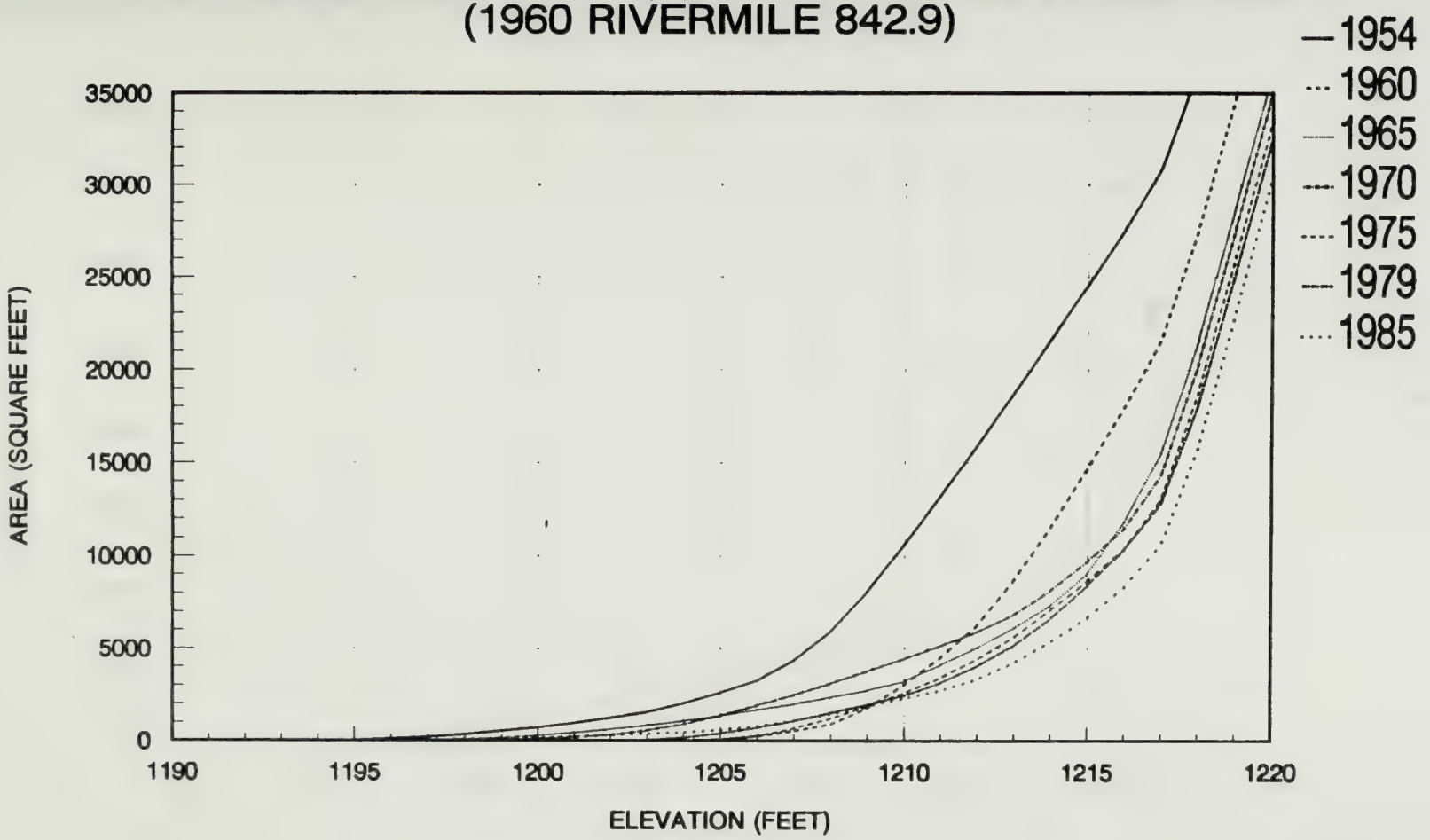
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 834.4

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 842.9)



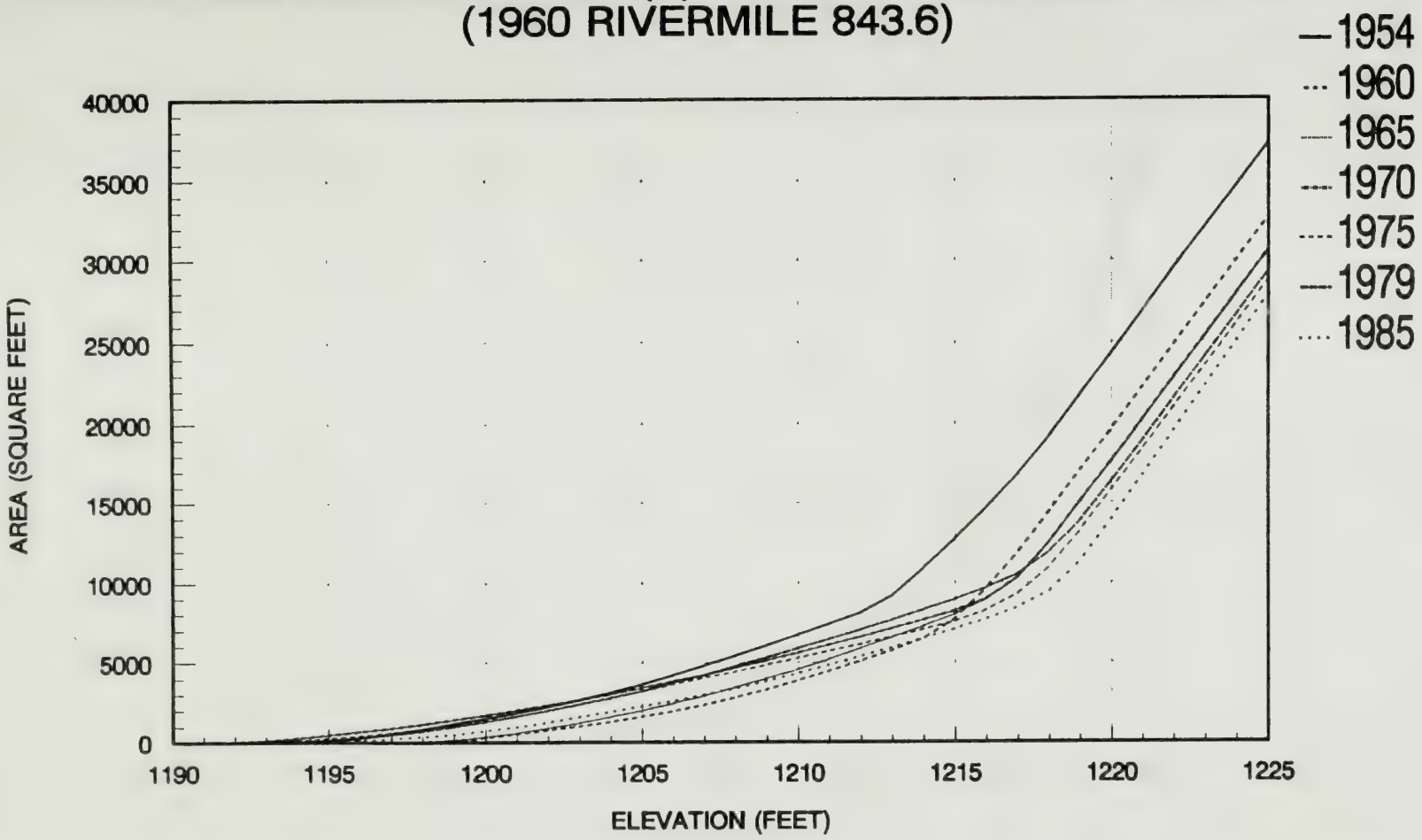
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 839.1

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 843.6)



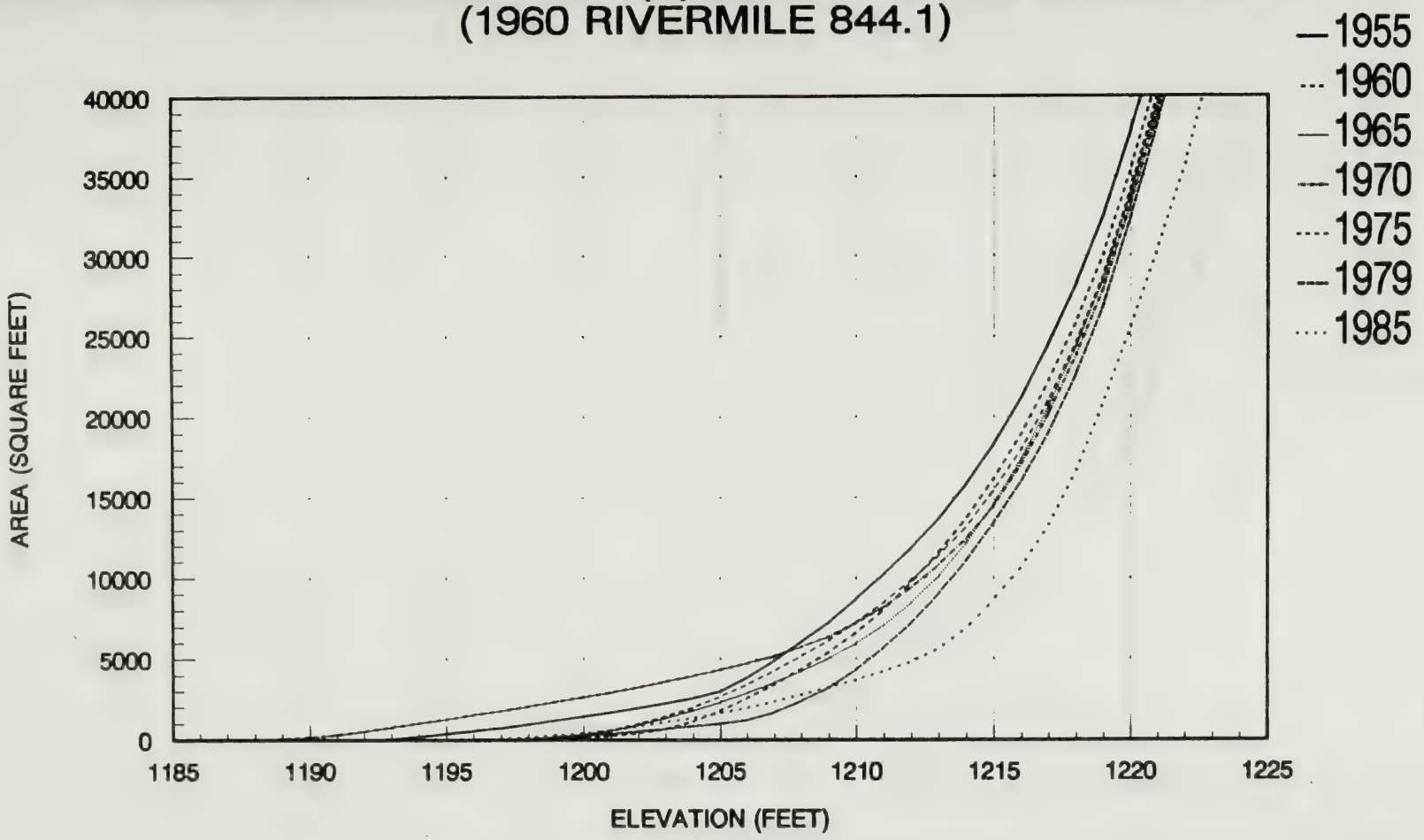
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 885.8

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 844.1)



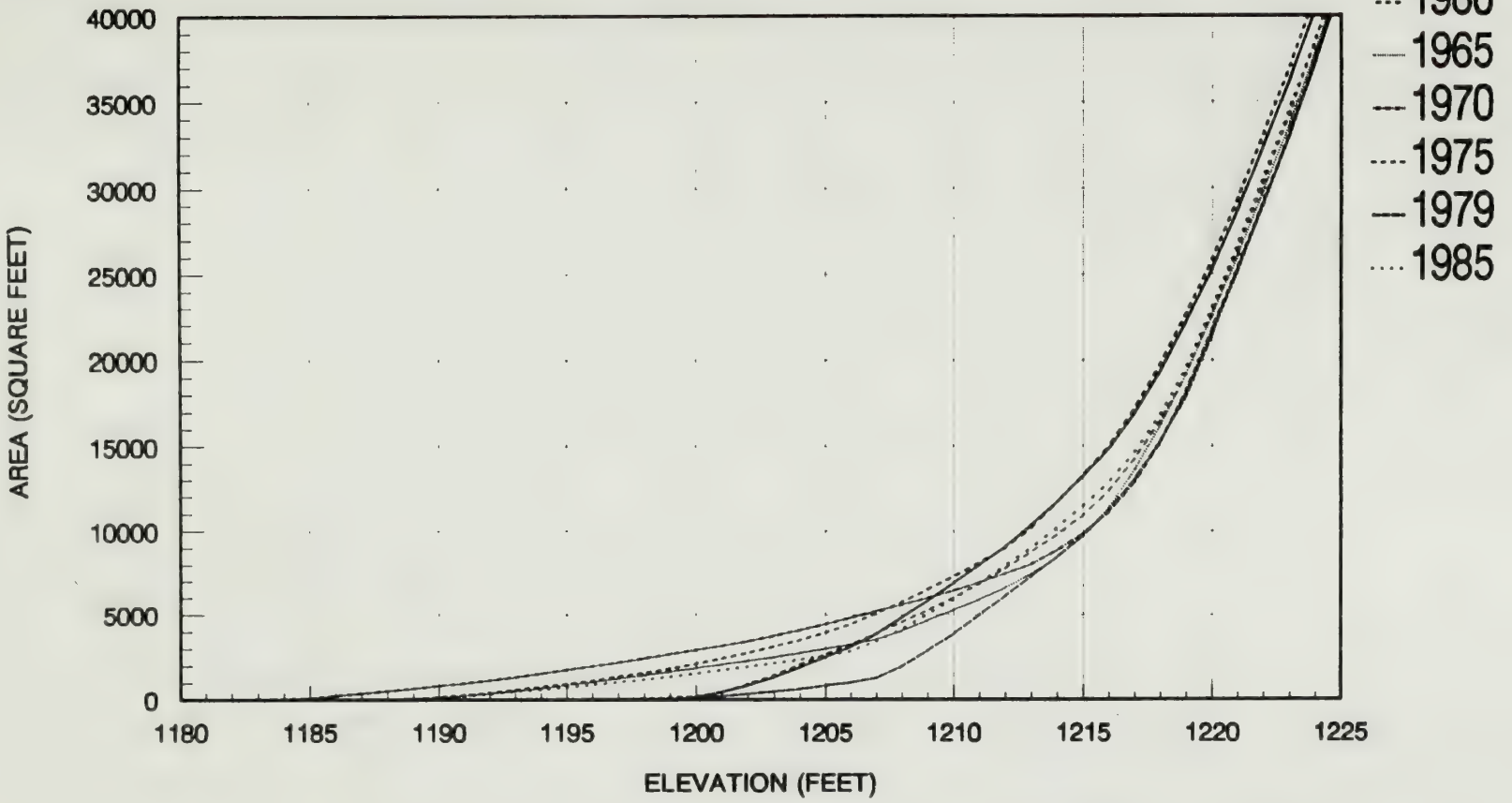
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 888.8

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 845.2)

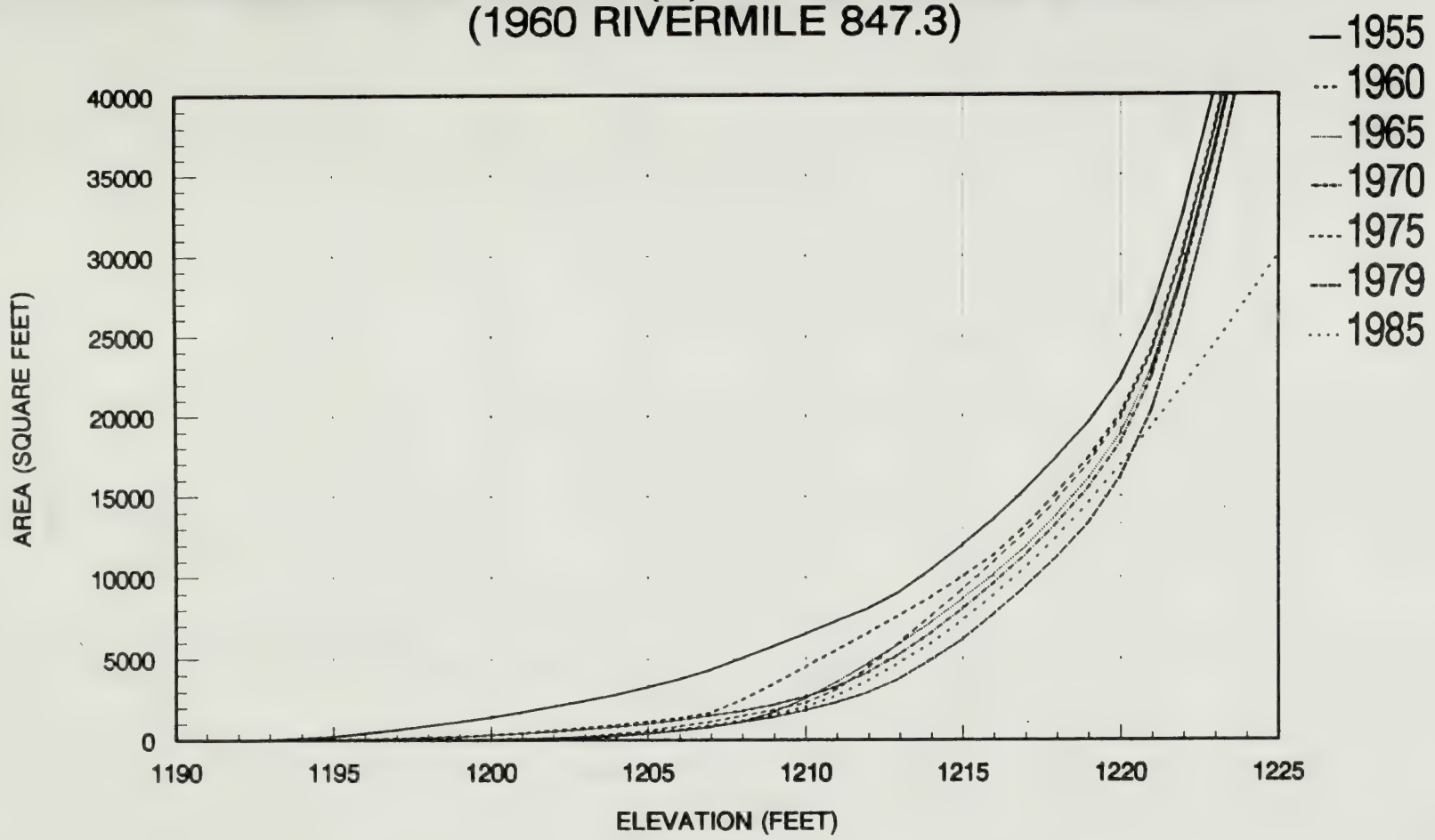


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

CROSS SECTION AREA (A) BELOW GIVEN ELEVATION
(1960 RIVERMILE 847.3)



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 0.0

MEAN DEPTH (D) BELOW GIVEN ELEVATION

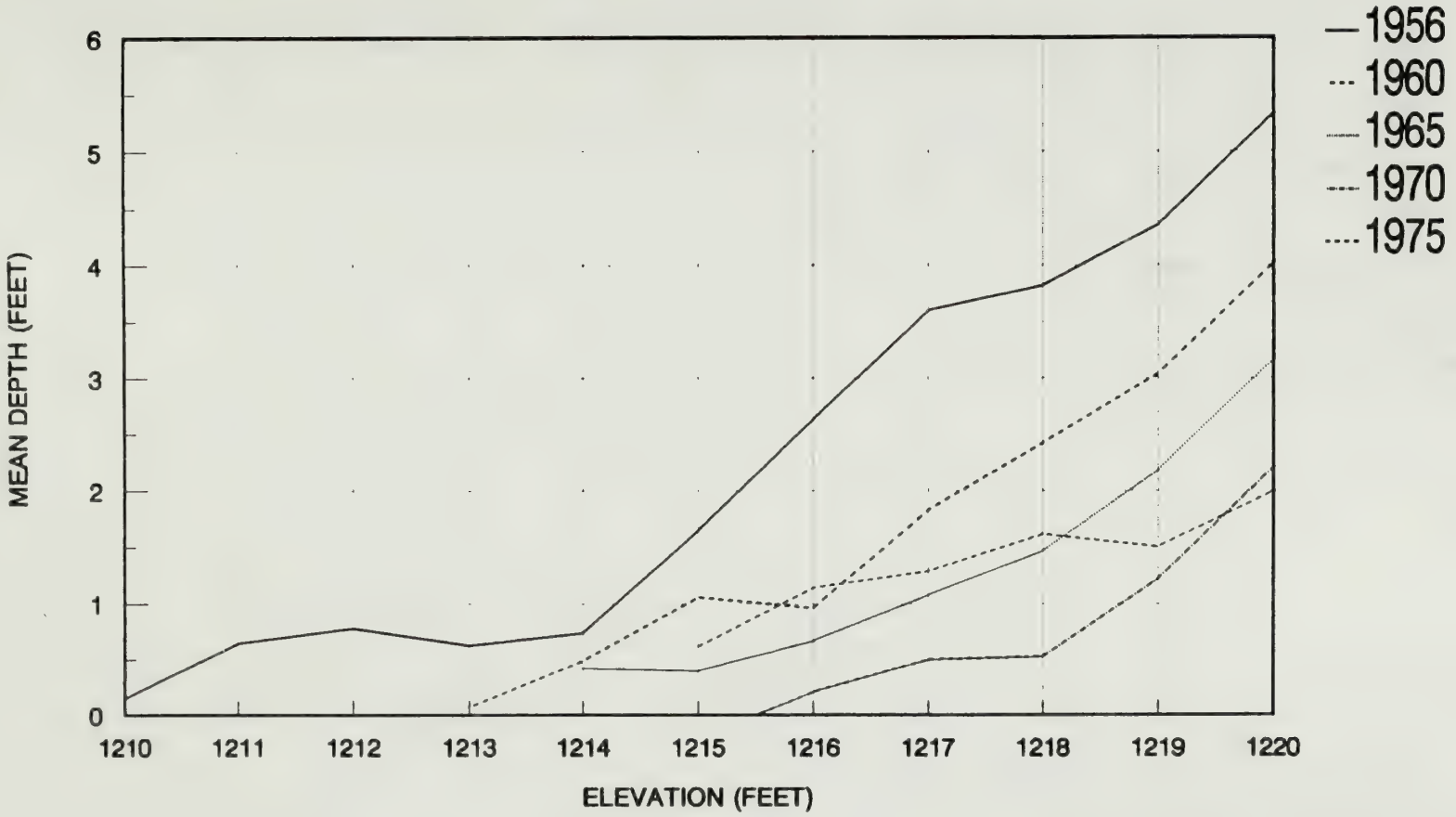


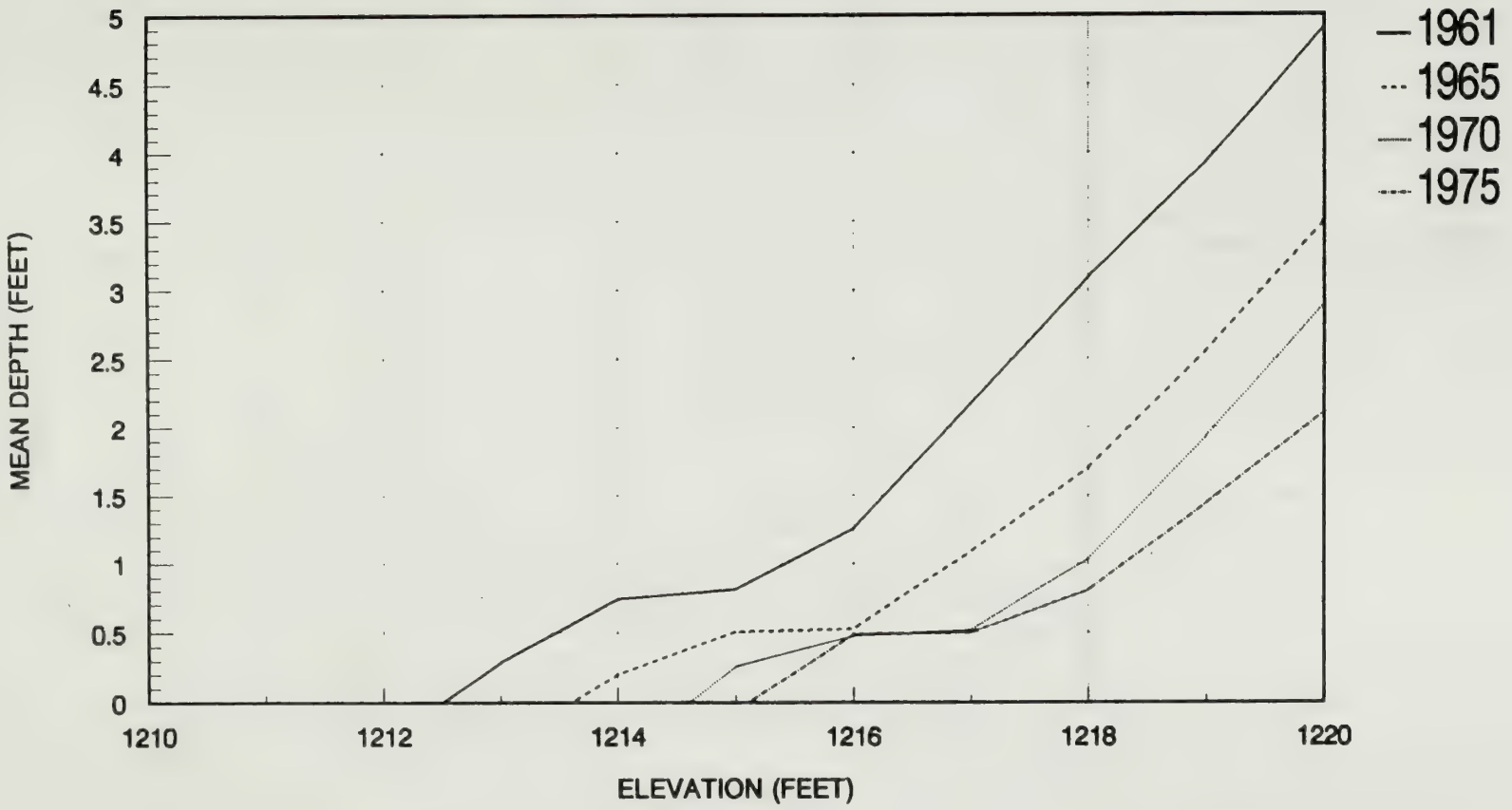
Plate IV.65

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 0.1
MEAN DEPTH (D) BELOW GIVEN ELEVATION

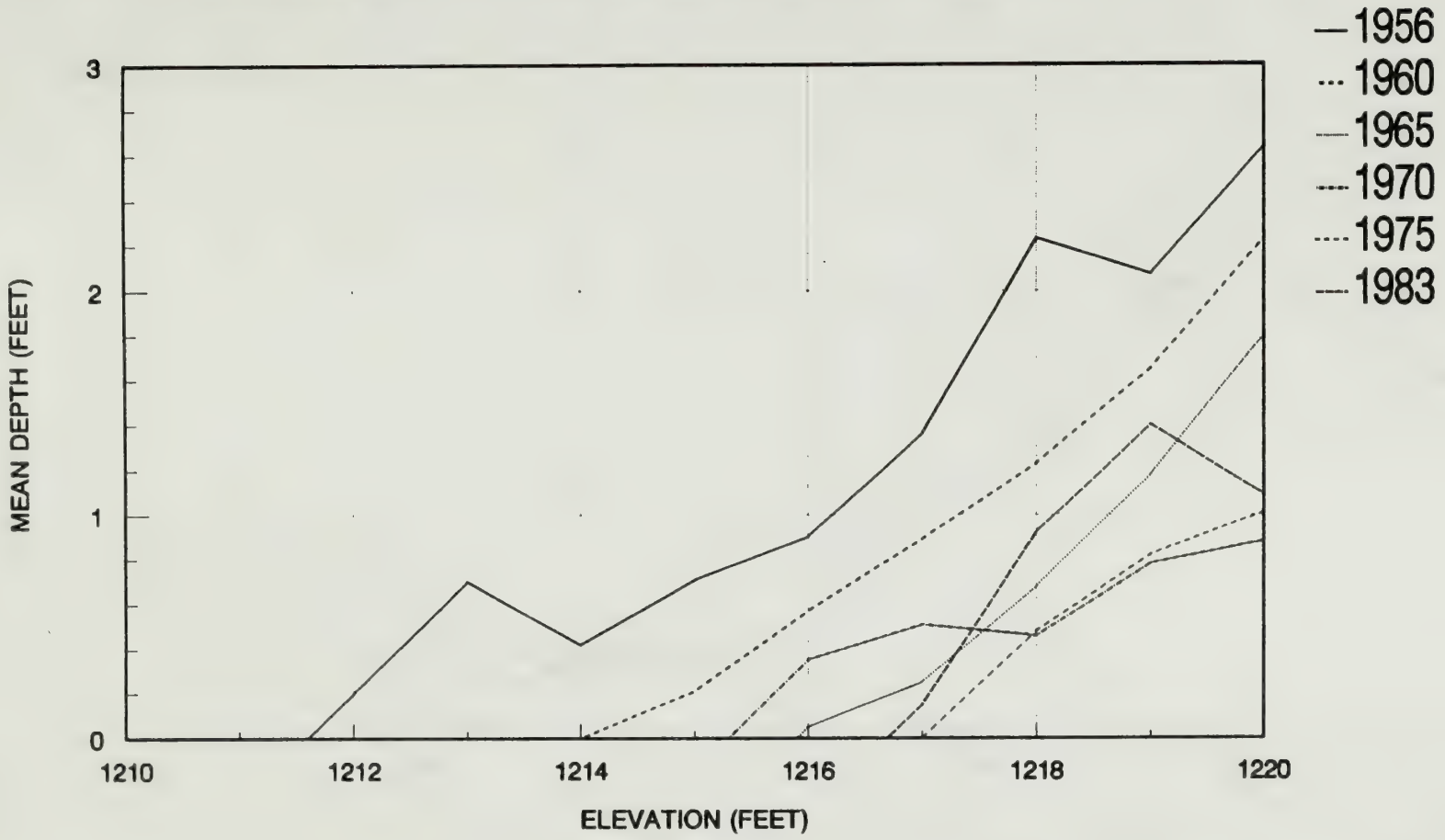


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 0.5
MEAN DEPTH (D) BELOW GIVEN ELEVATION

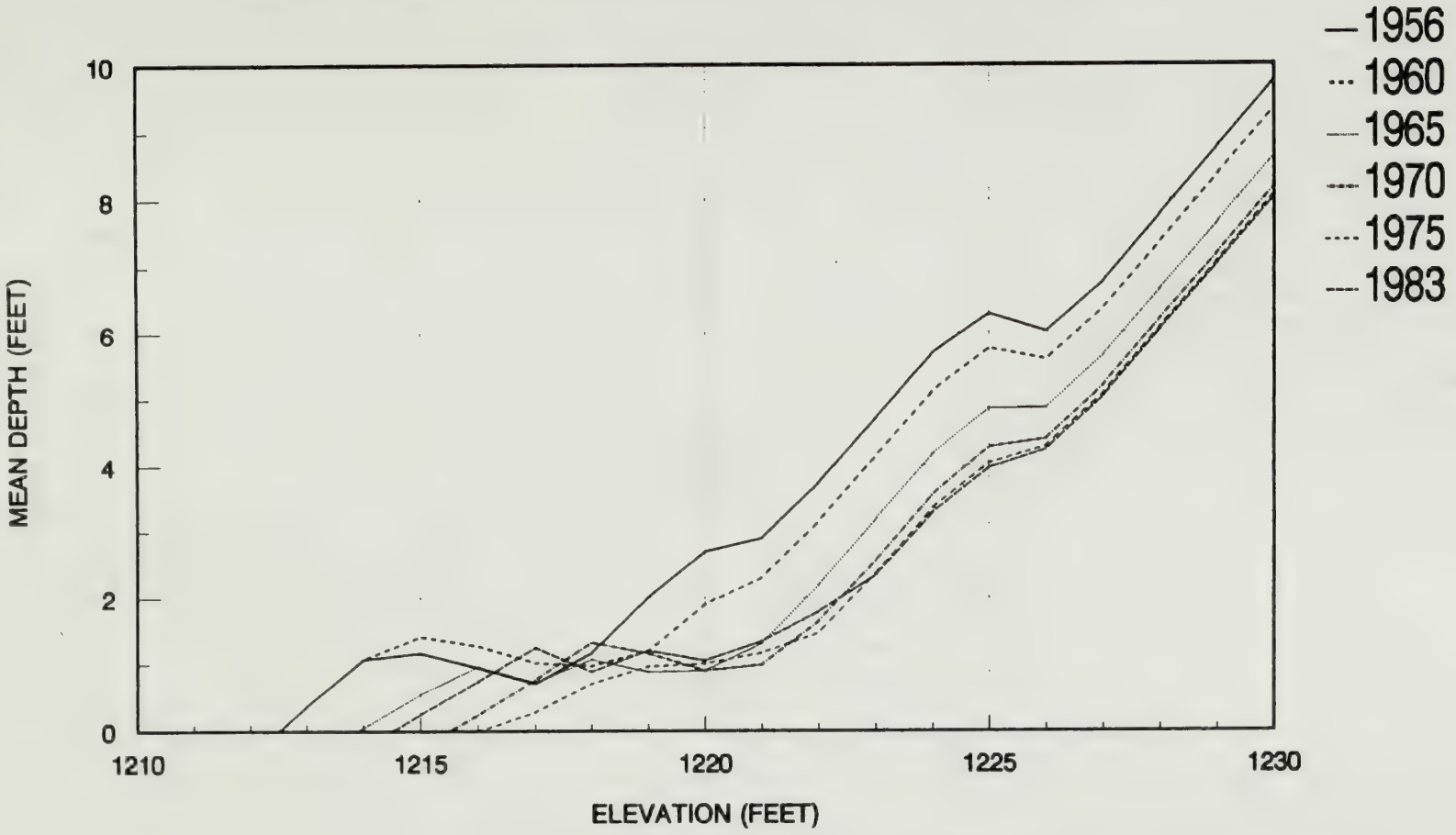


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 0.8
MEAN DEPTH (D) BELOW GIVEN ELEVATION

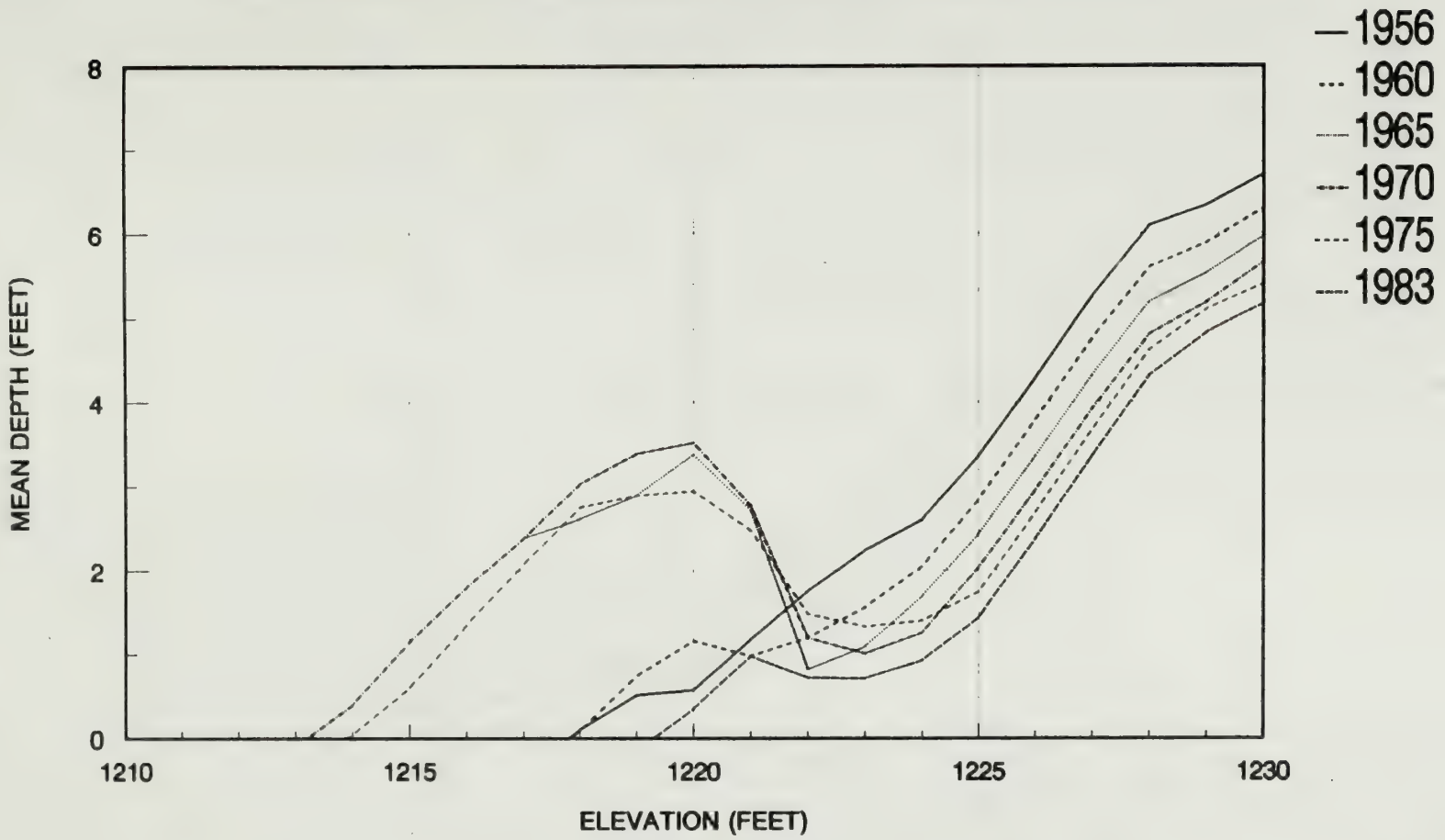


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 1.1
MEAN DEPTH (D) BELOW GIVEN ELEVATION



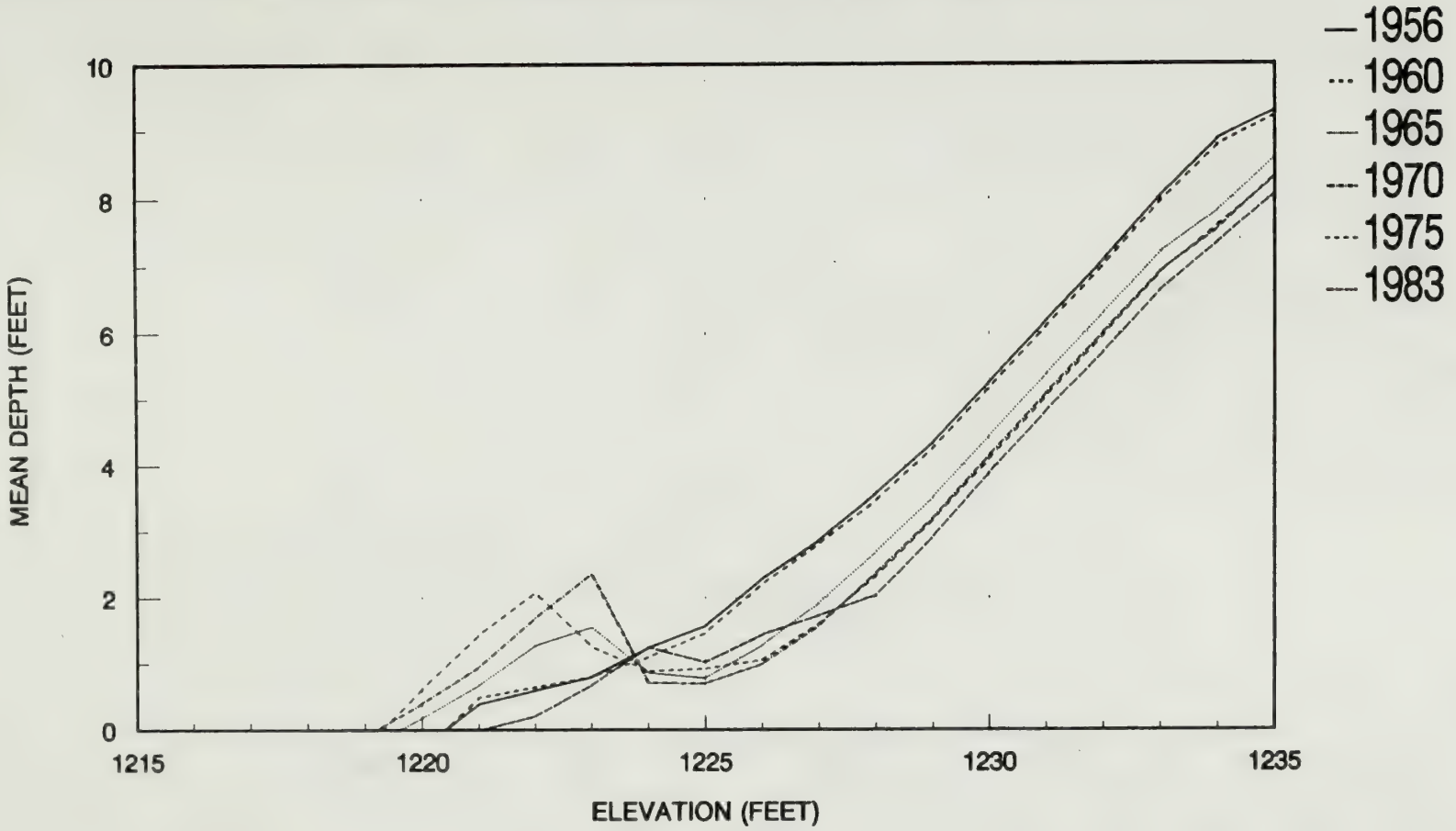
NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 1.4

MEAN DEPTH (D) BELOW GIVEN ELEVATION

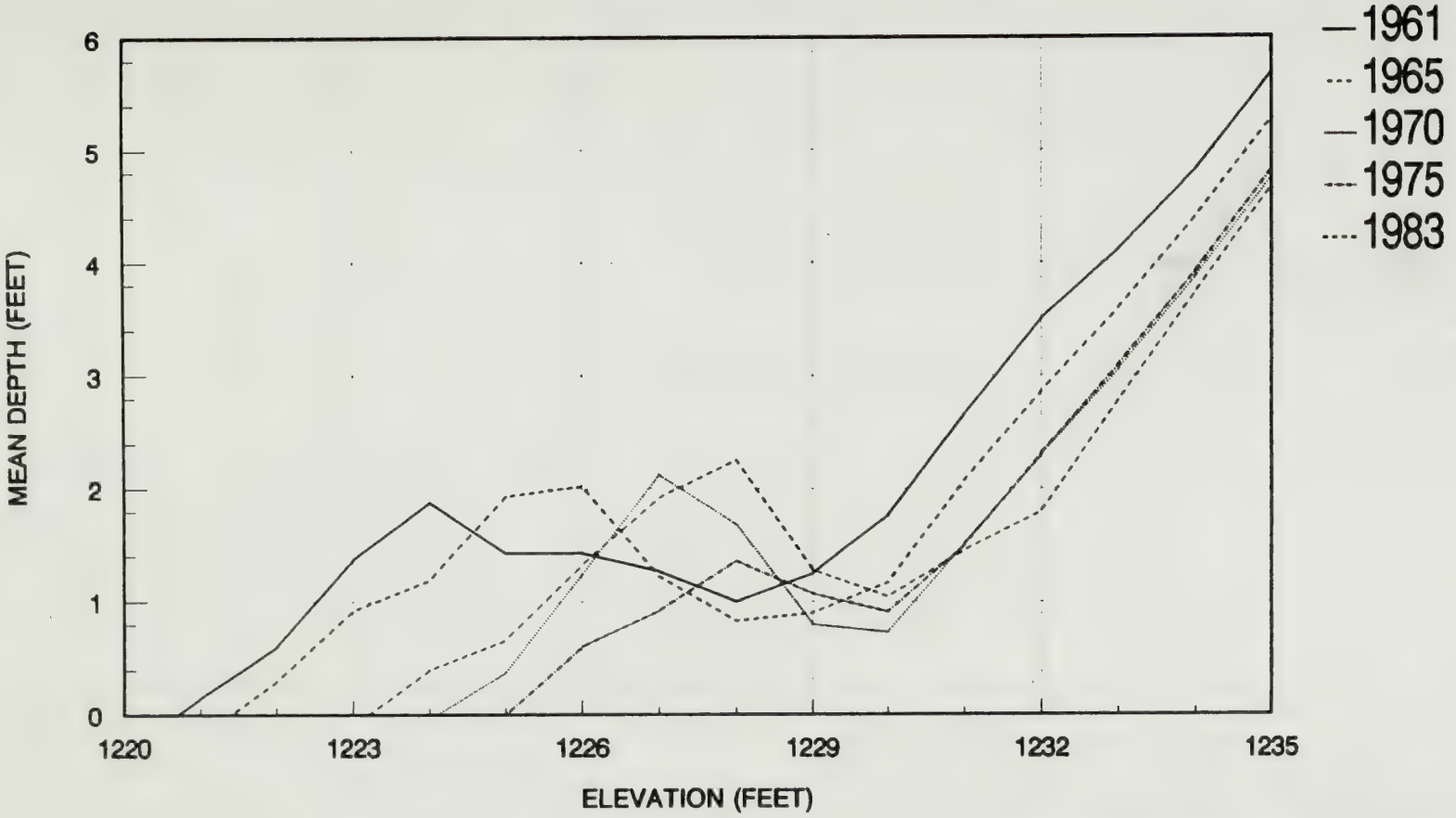


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 1.9
MEAN DEPTH (D) BELOW GIVEN ELEVATION

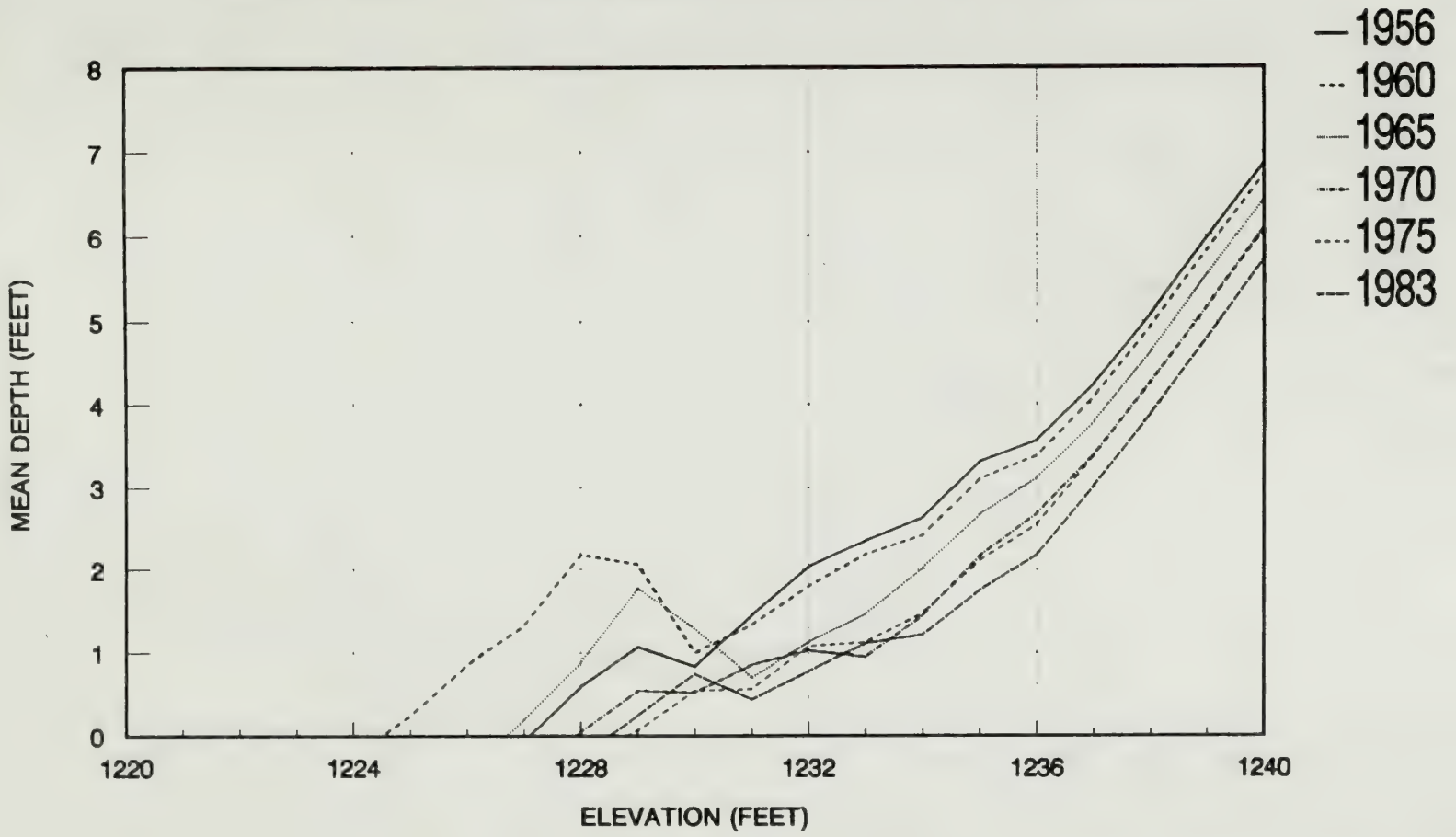


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 2.4
MEAN DEPTH (D) BELOW GIVEN ELEVATION



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 3.0

MEAN DEPTH (D) BELOW GIVEN ELEVATION

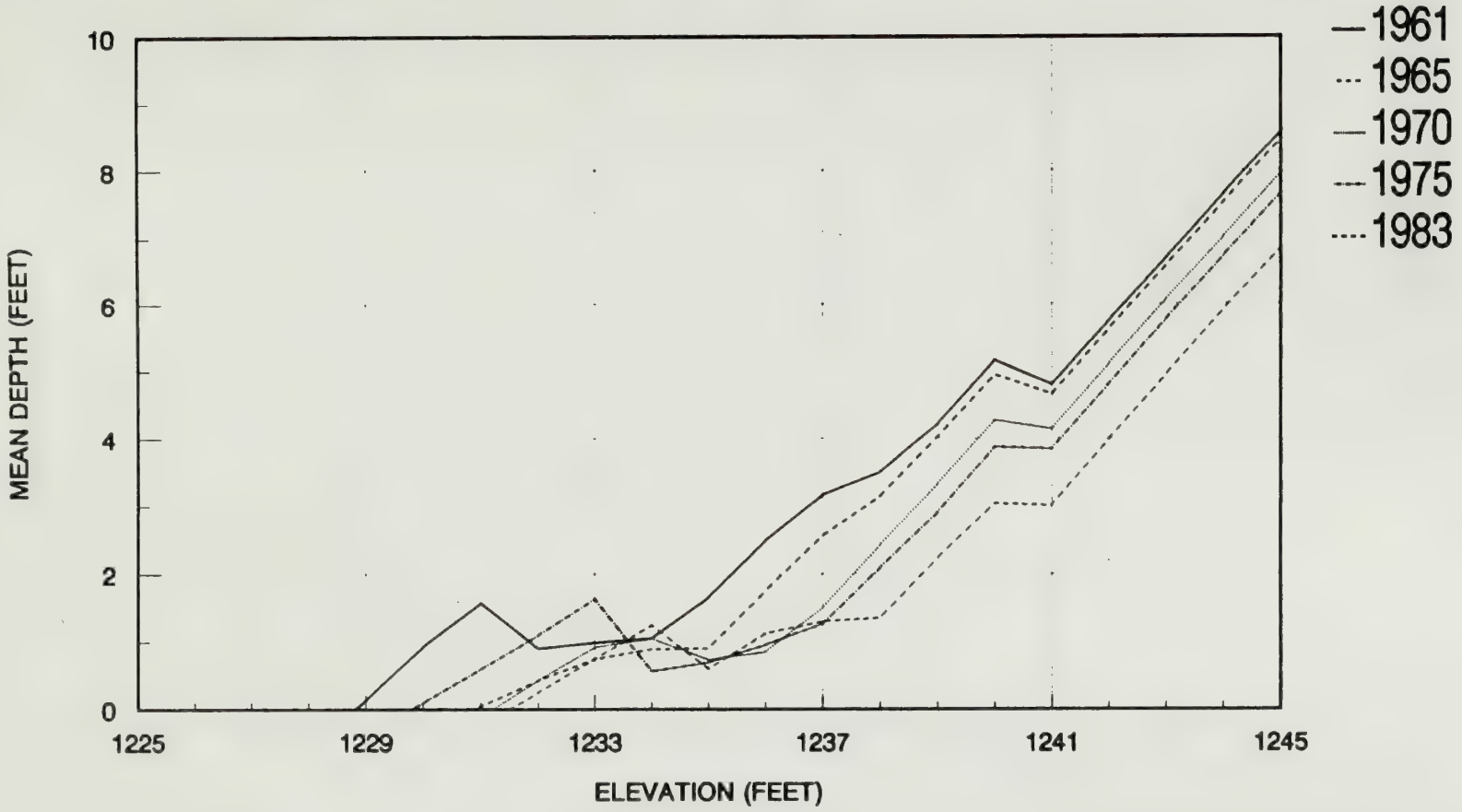


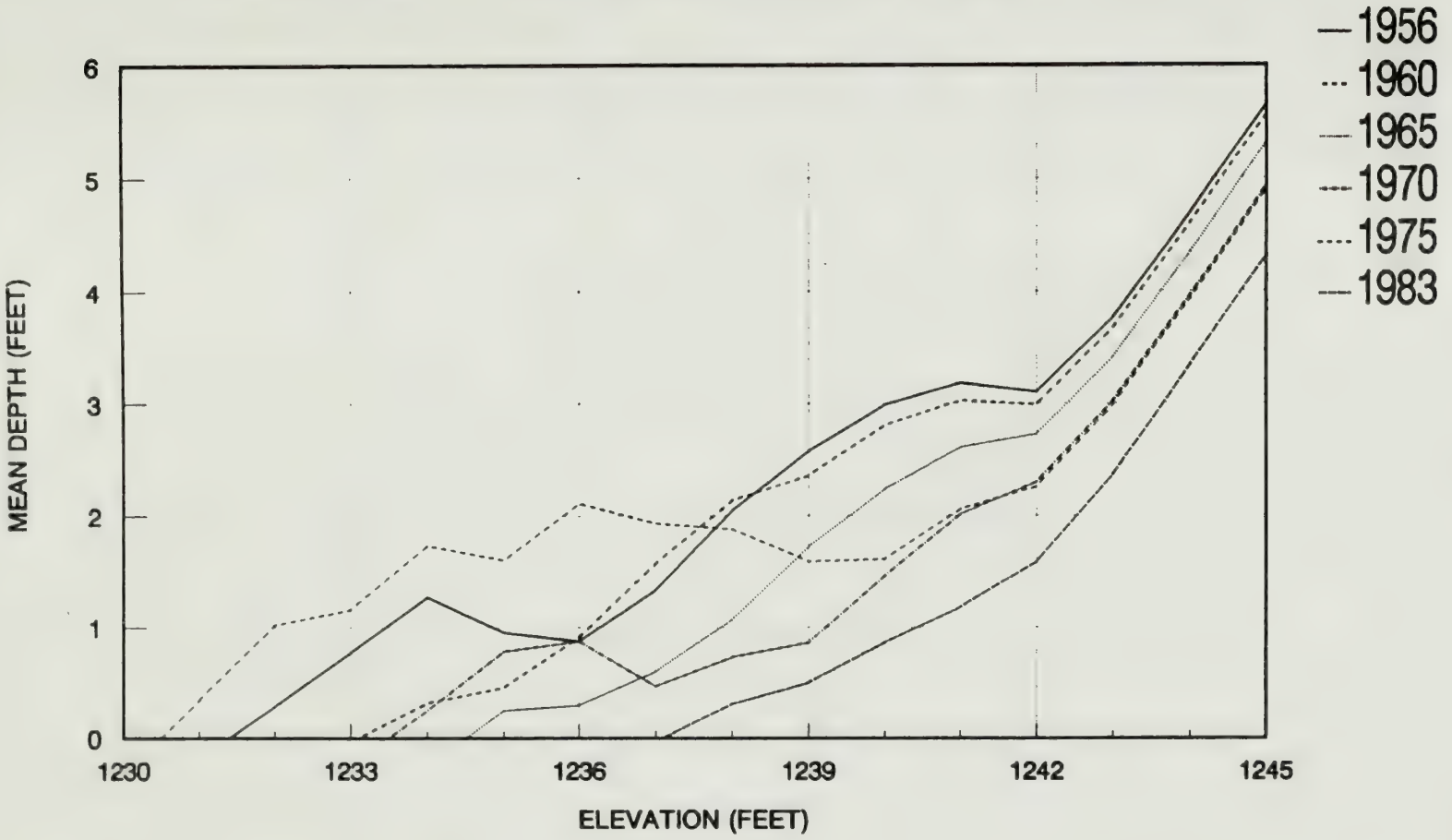
Plate IV.73

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 3.6
MEAN DEPTH (D) BELOW GIVEN ELEVATION

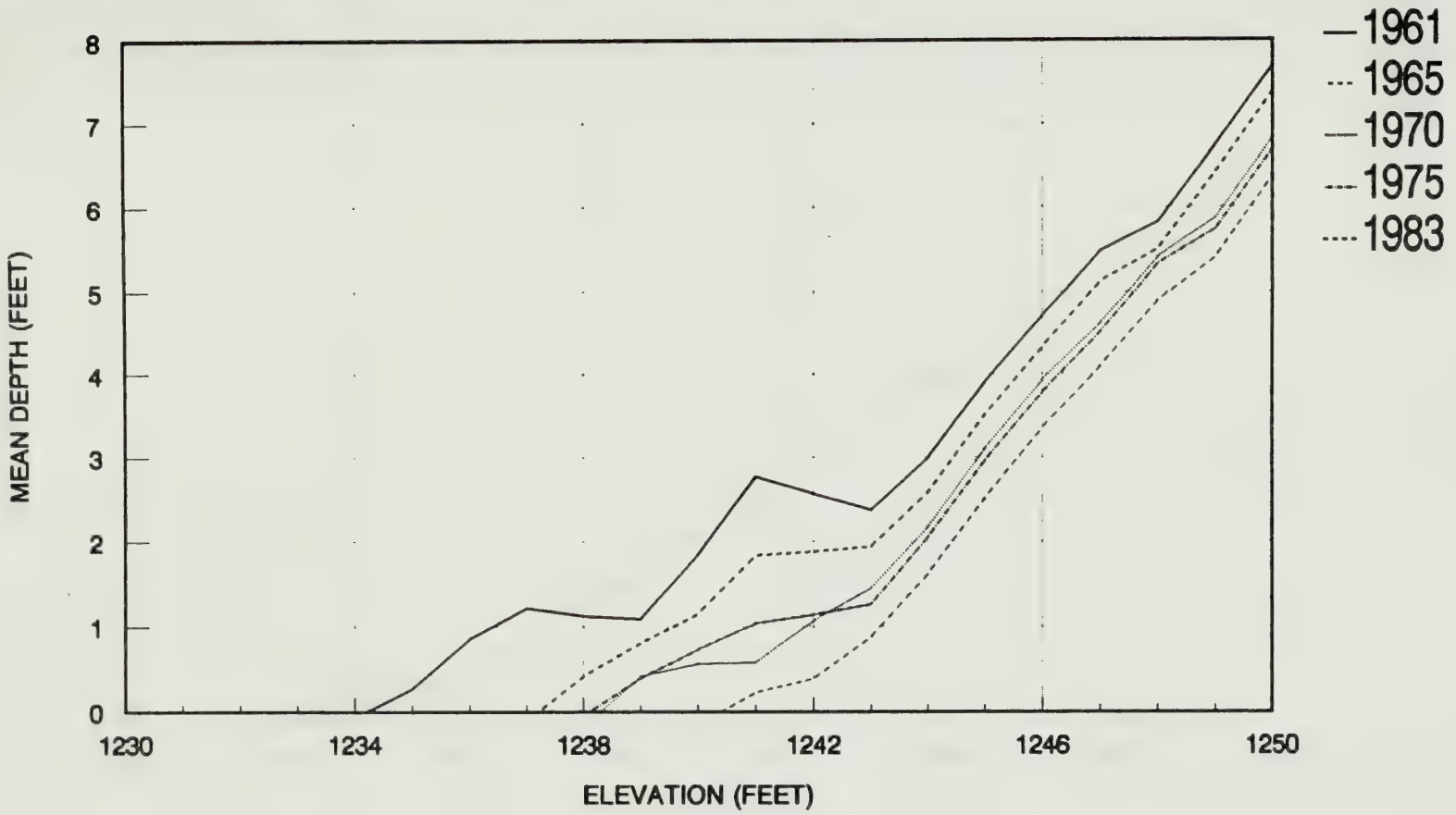


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 4.0
MEAN DEPTH (D) BELOW GIVEN ELEVATION

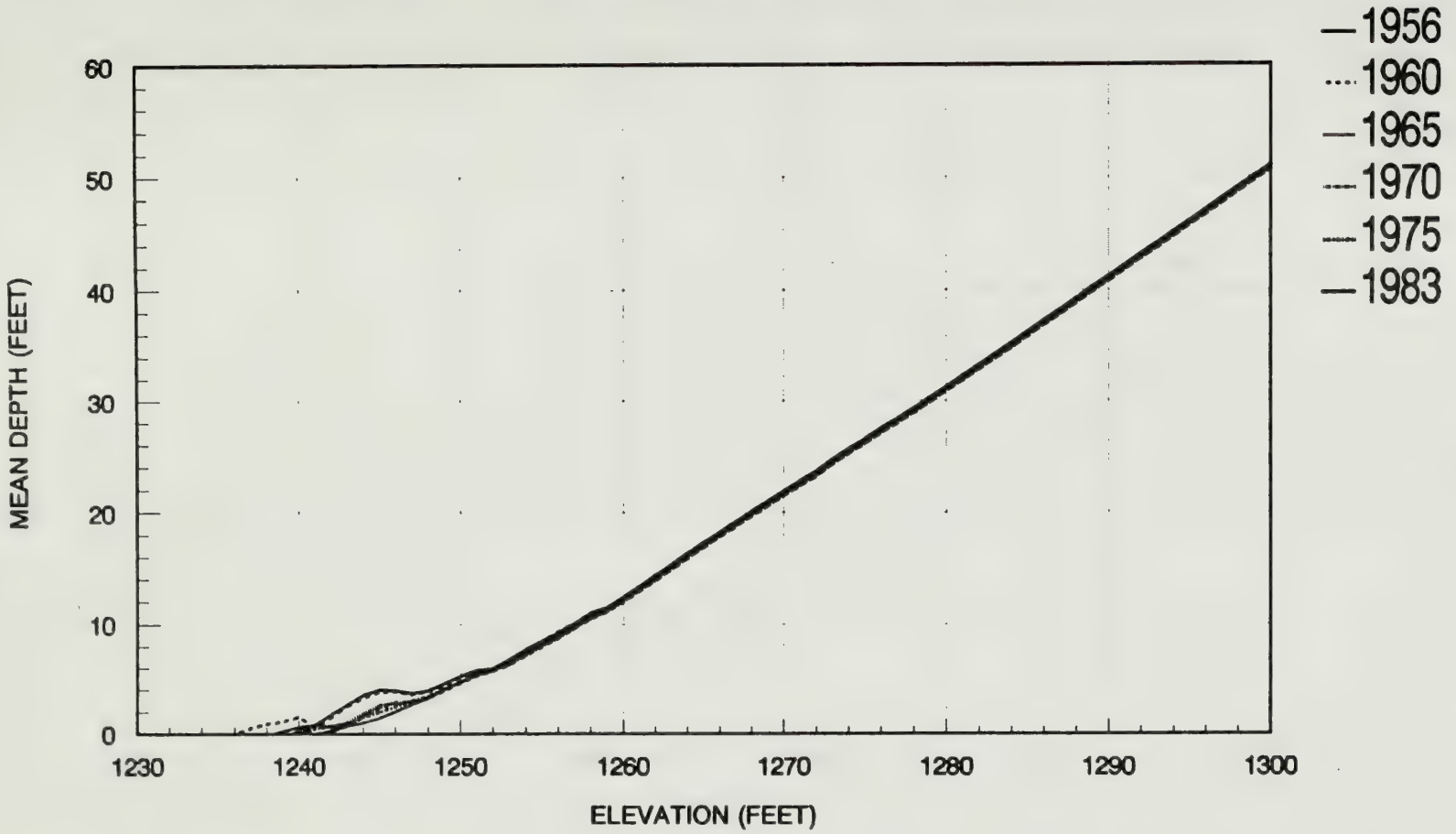


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 4.4
MEAN DEPTH (D) BELOW GIVEN ELEVATION

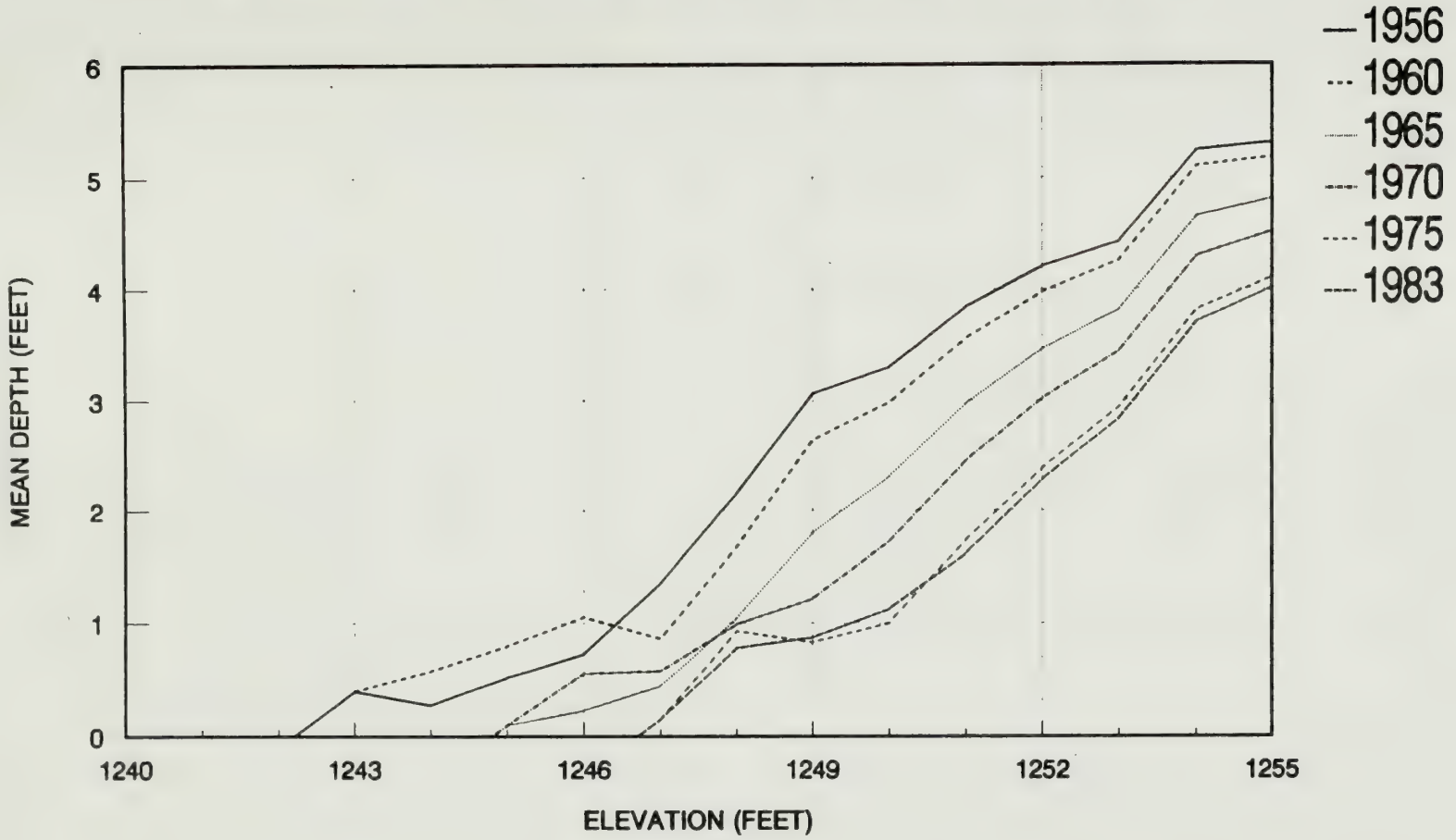


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 5.2
MEAN DEPTH (D) BELOW GIVEN ELEVATION

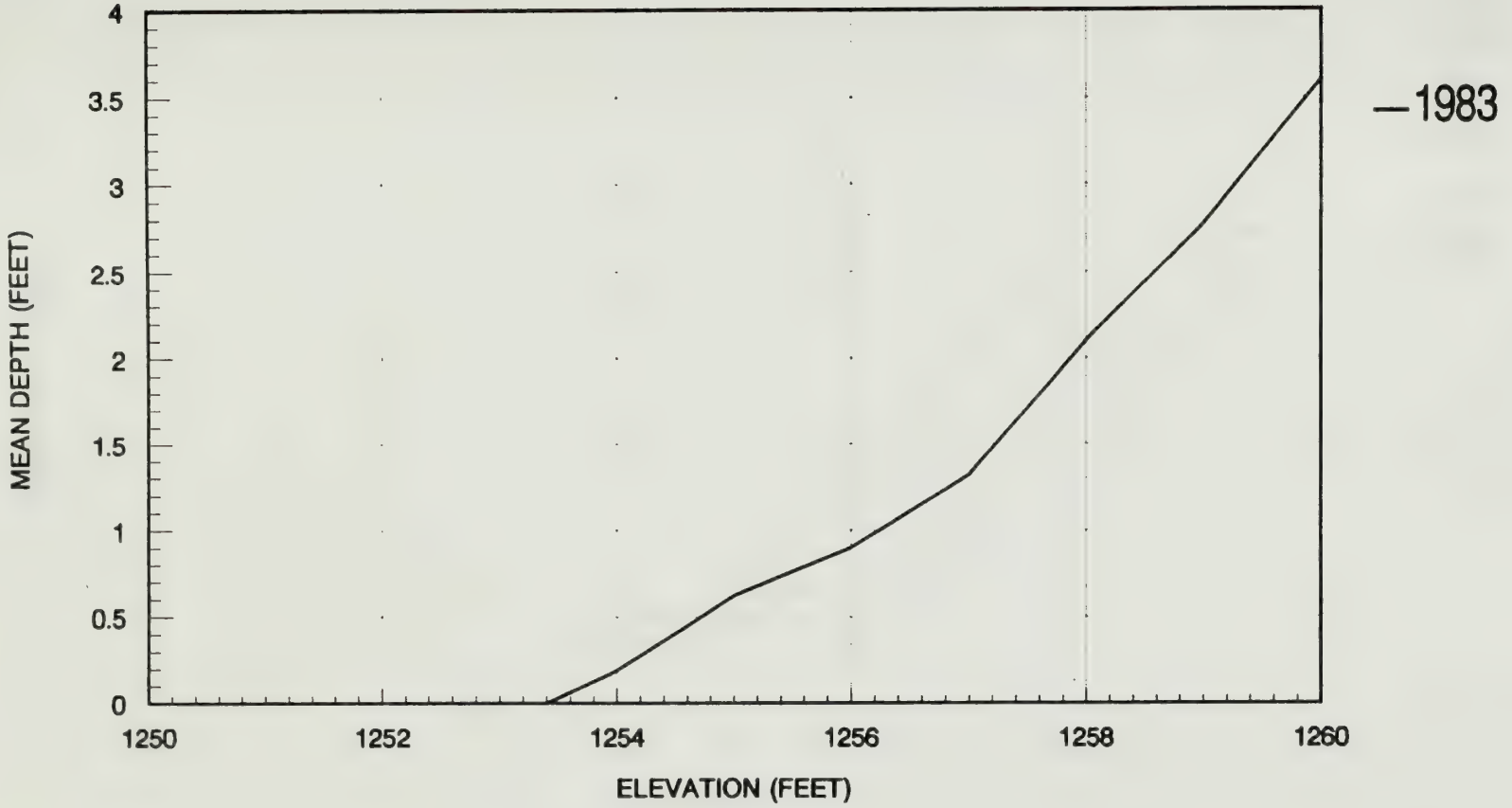


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 6.0
MEAN DEPTH (D) BELOW GIVEN ELEVATION

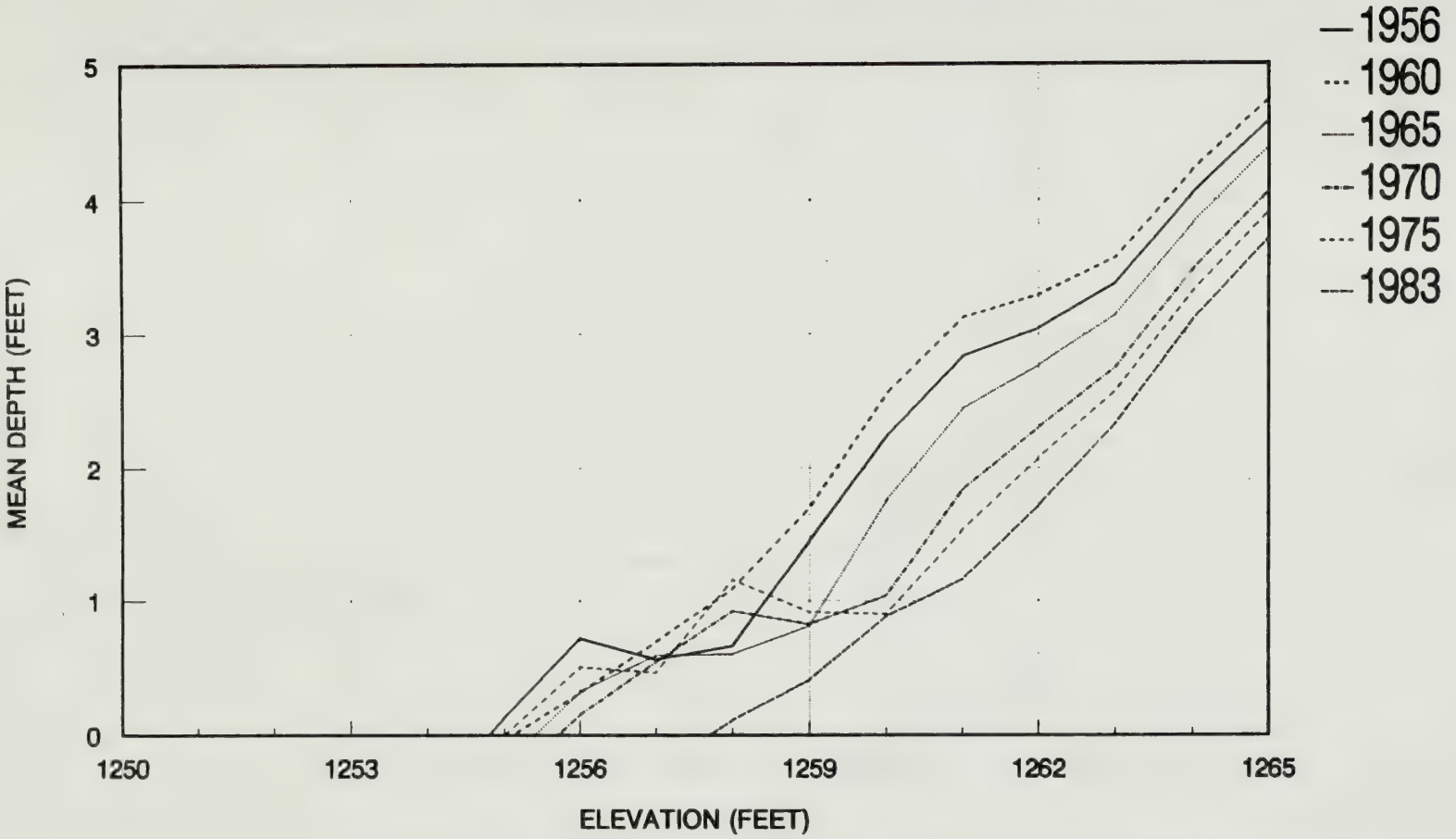


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 6.9
MEAN DEPTH (D) BELOW GIVEN ELEVATION

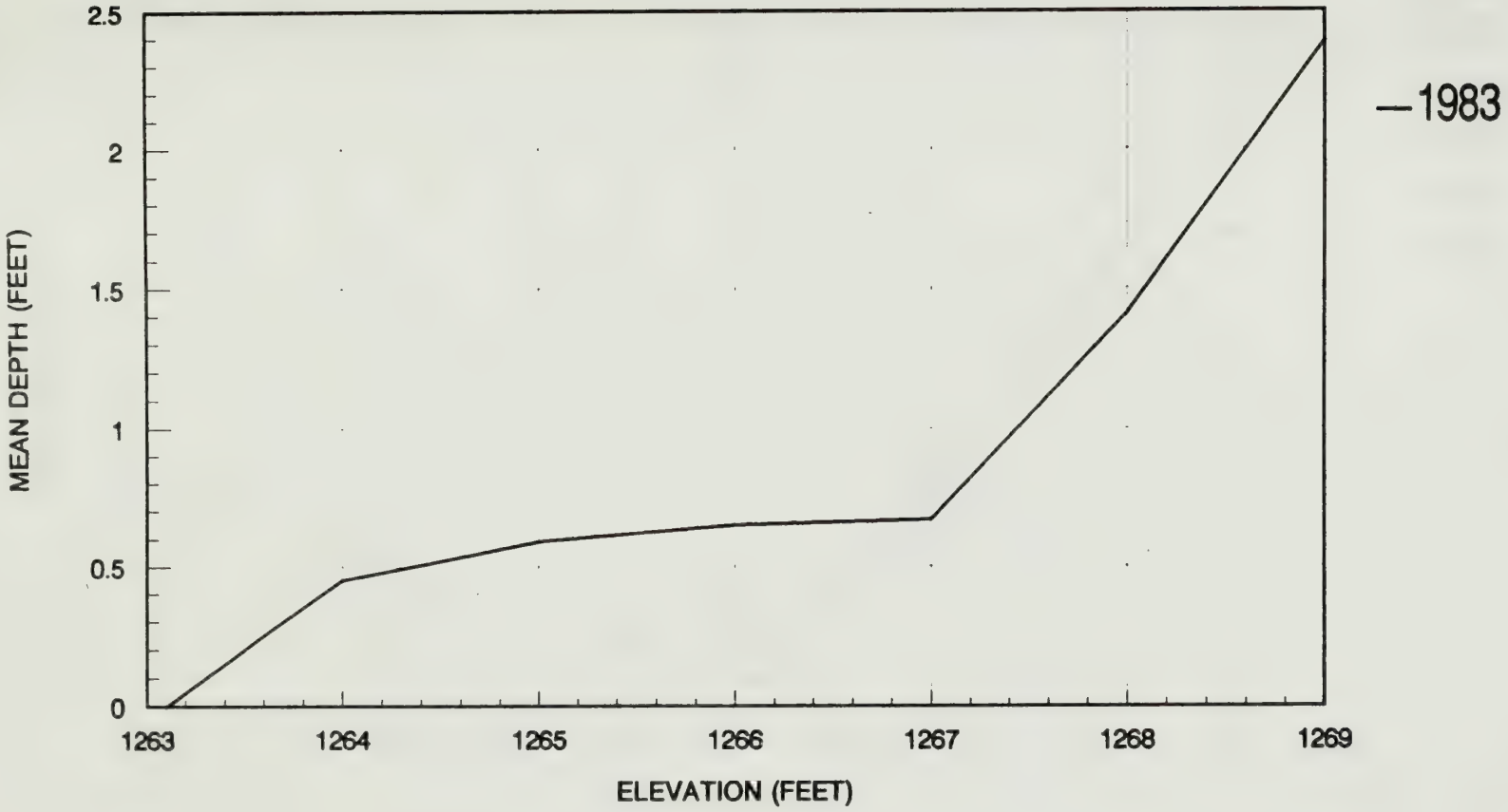


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 8.0
MEAN DEPTH (D) BELOW GIVEN ELEVATION

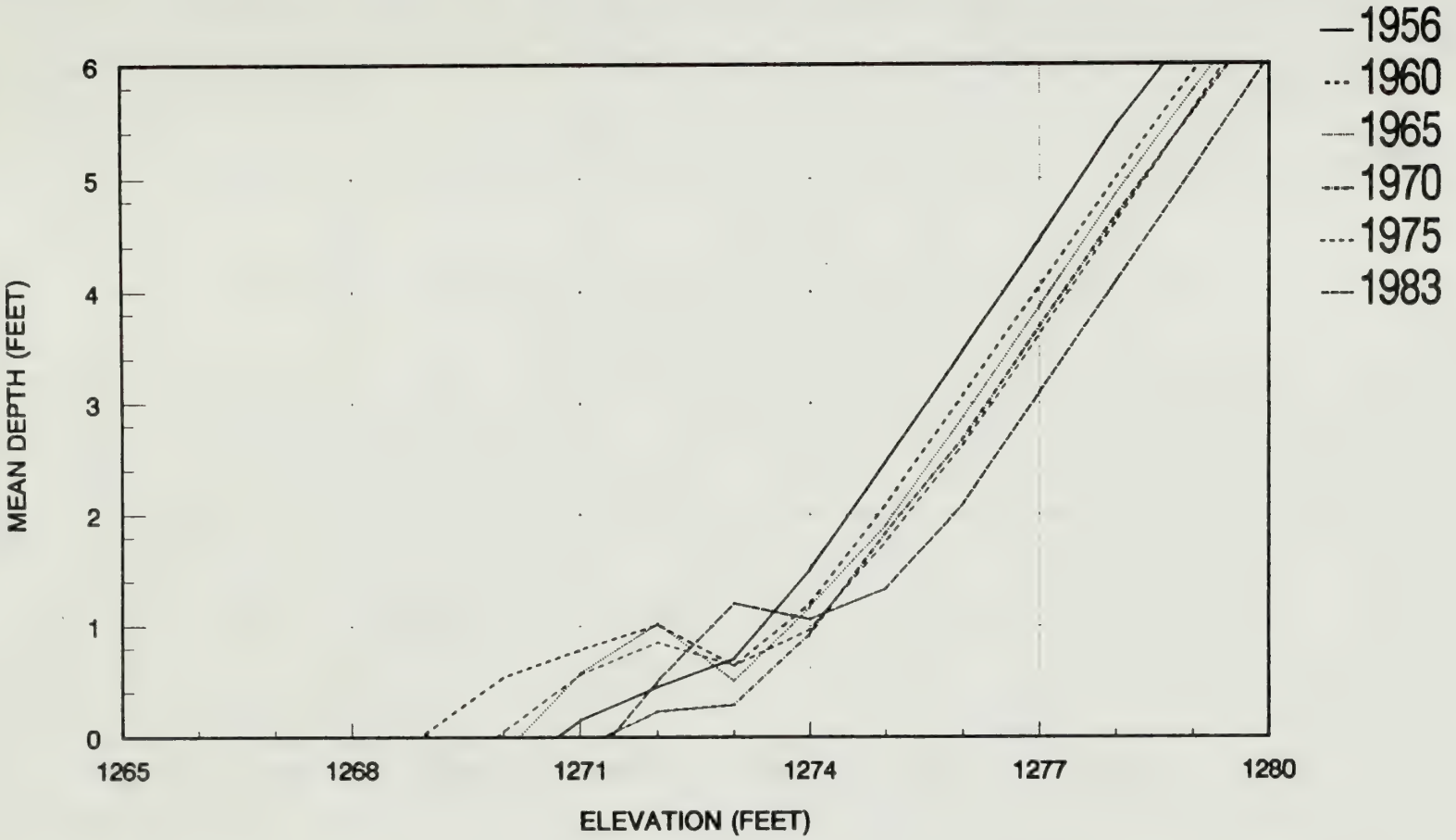


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N 9.0
MEAN DEPTH (D) BELOW GIVEN ELEVATION



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N10.5
MEAN DEPTH (D) BELOW GIVEN ELEVATION

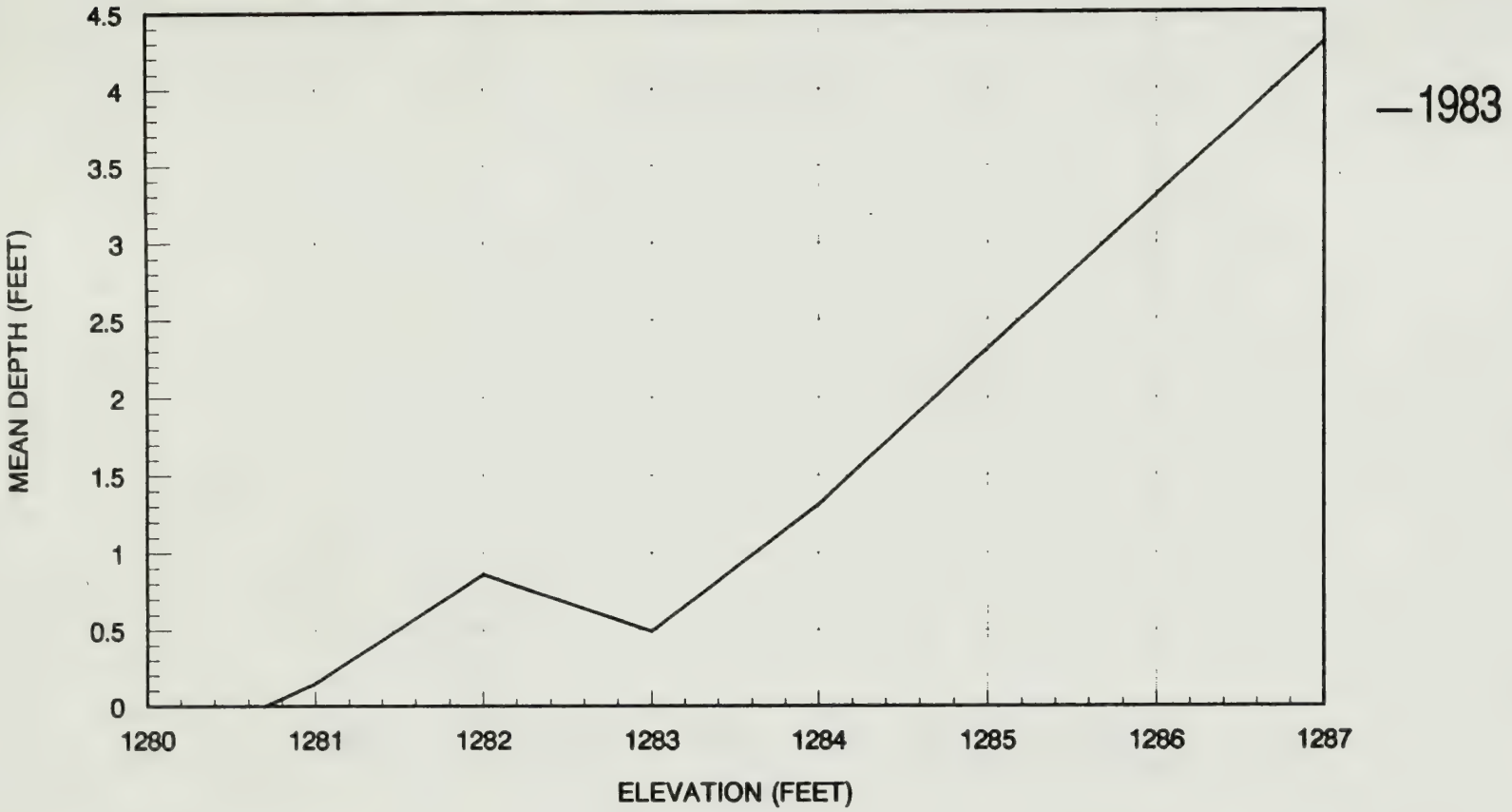


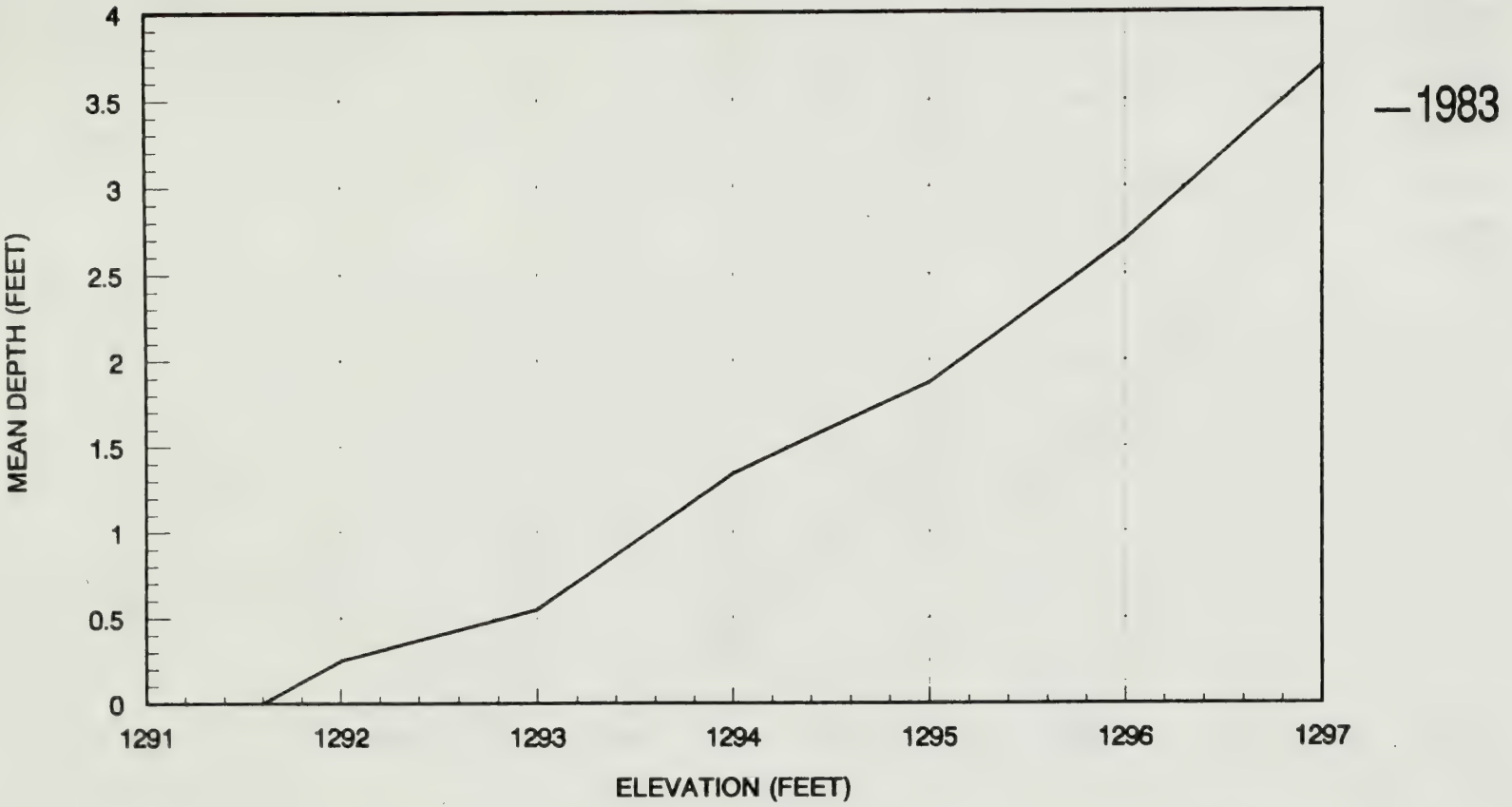
Plate IV.82

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N11.6
MEAN DEPTH (D) BELOW GIVEN ELEVATION

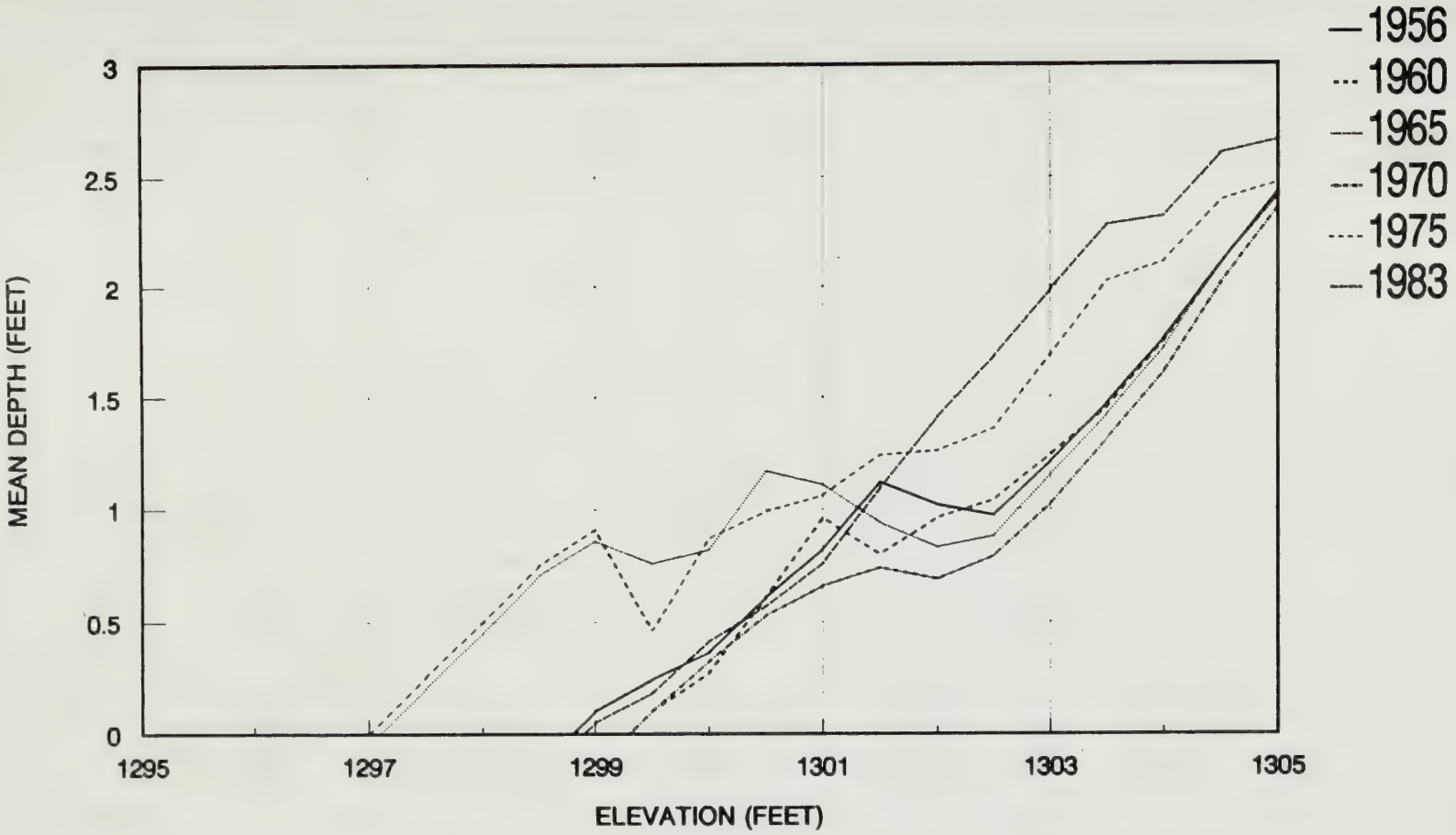


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N13.0
MEAN DEPTH (D) BELOW GIVEN ELEVATION

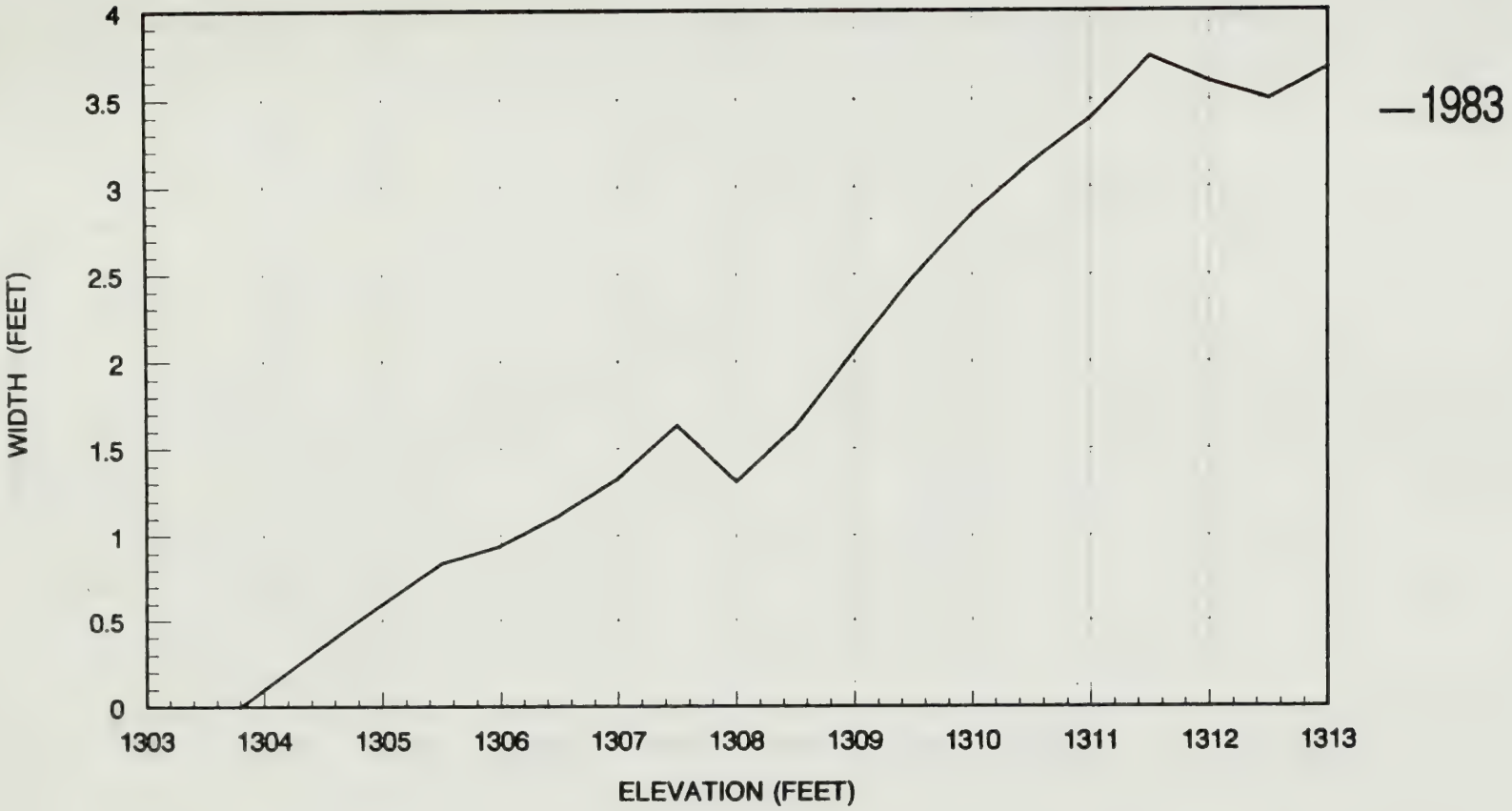


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N13.8
CHANNEL DEPTH (W) AT GIVEN ELEVATION

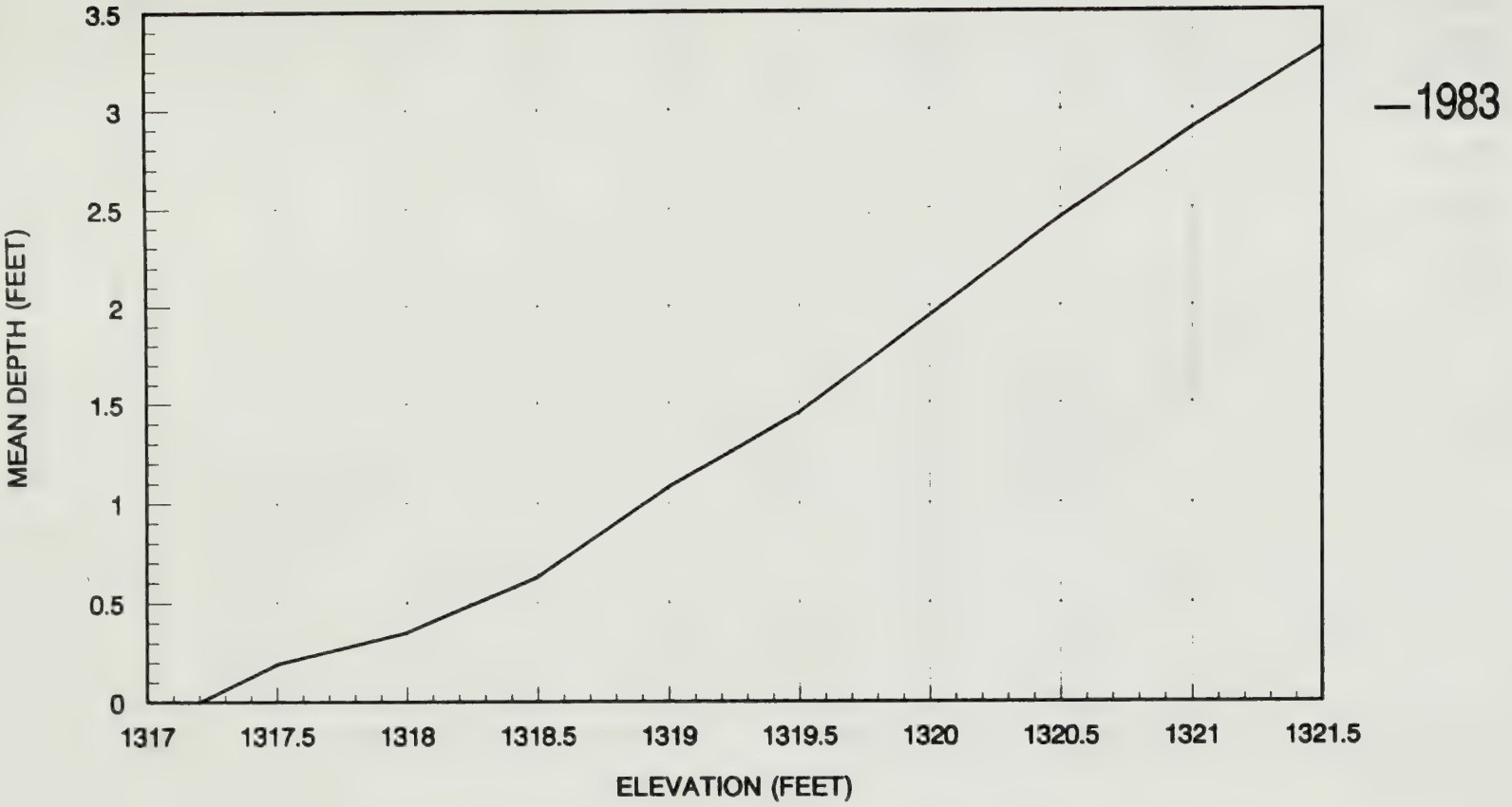


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER RANGE N14.5
MEAN DEPTH (D) BELOW GIVEN ELEVATION



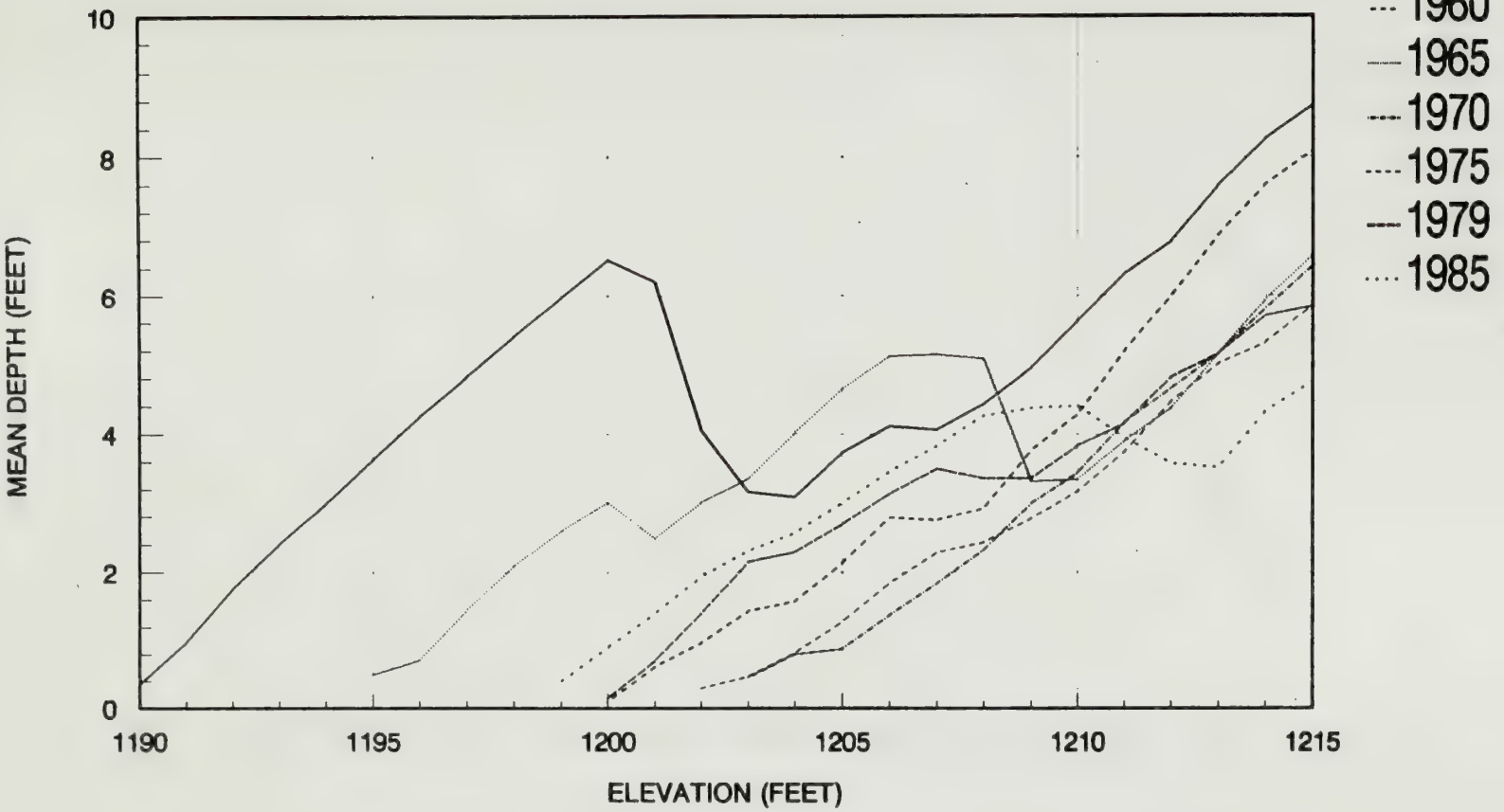
NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 881.4

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 840.0)



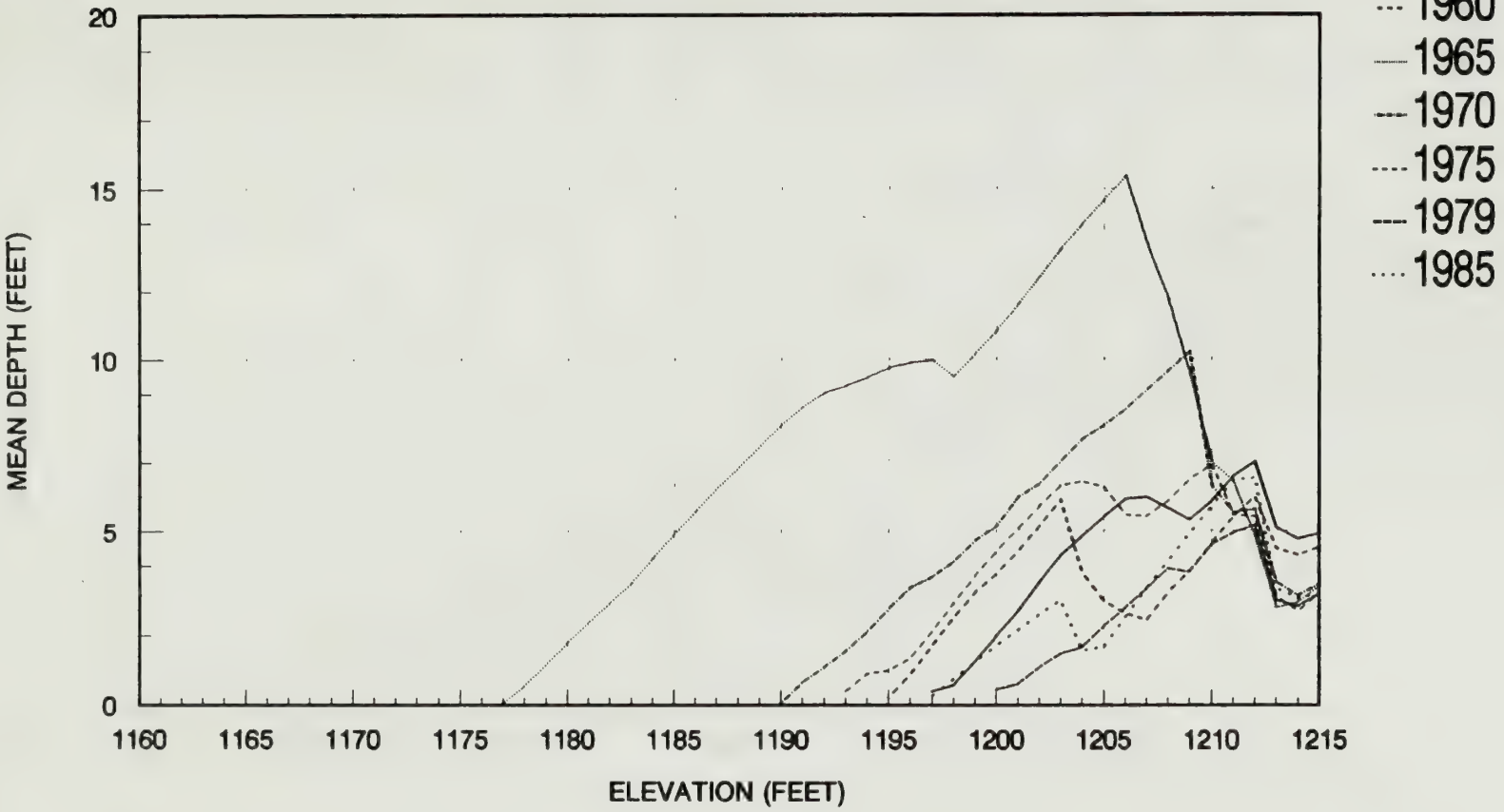
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 882.0

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 840.6)



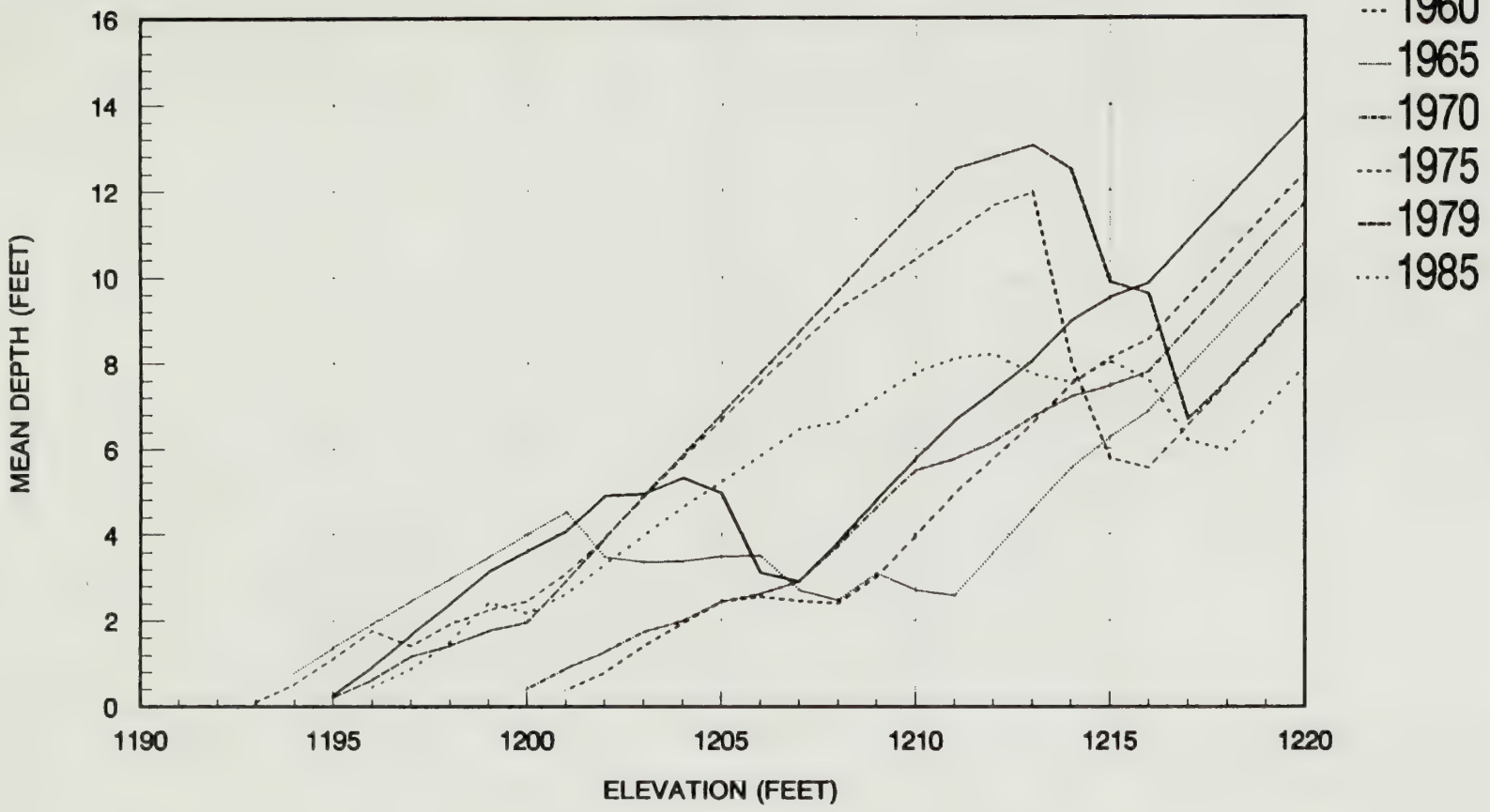
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 882.6

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 841.2)



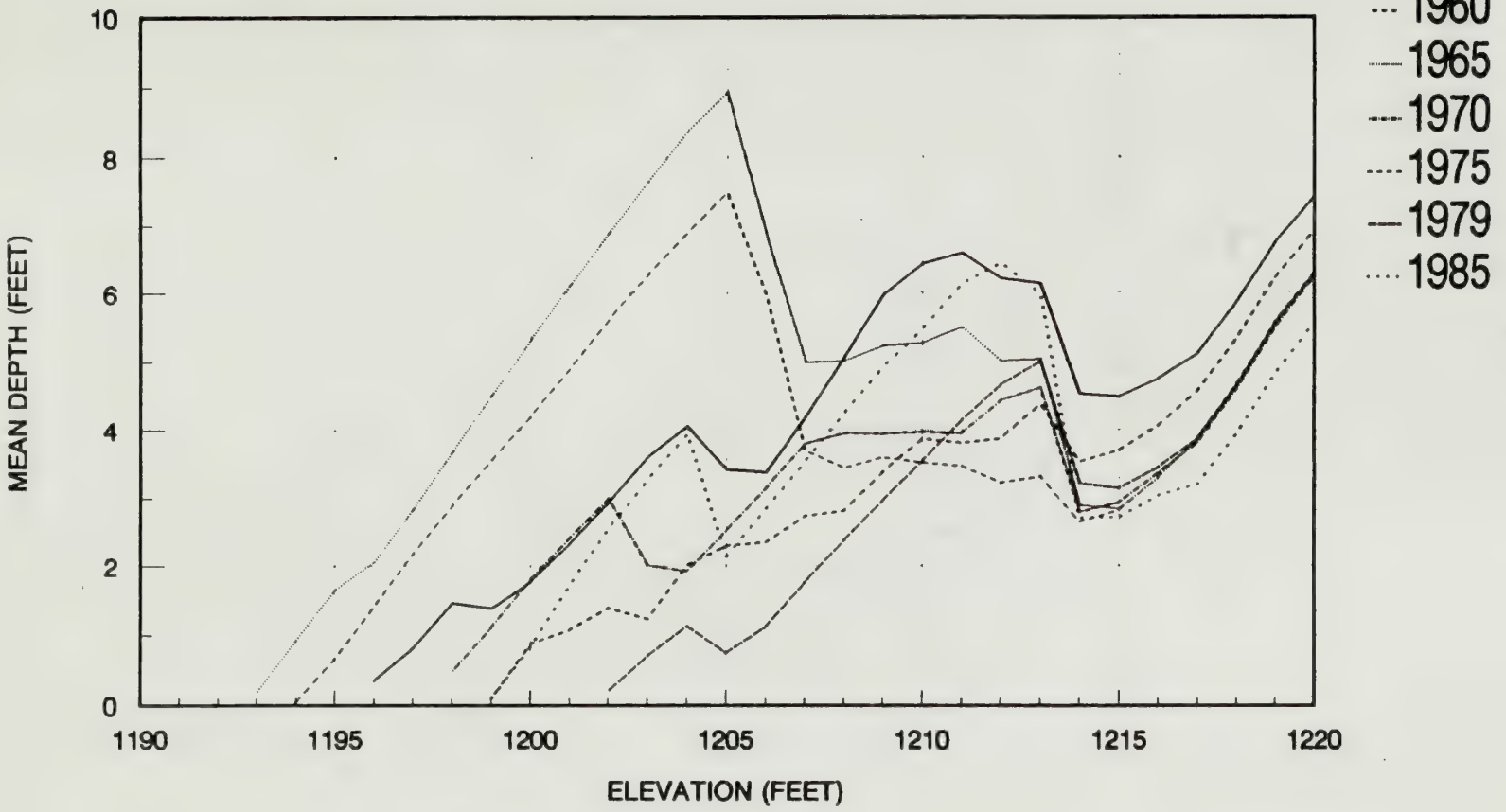
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 883.3

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 841.9)



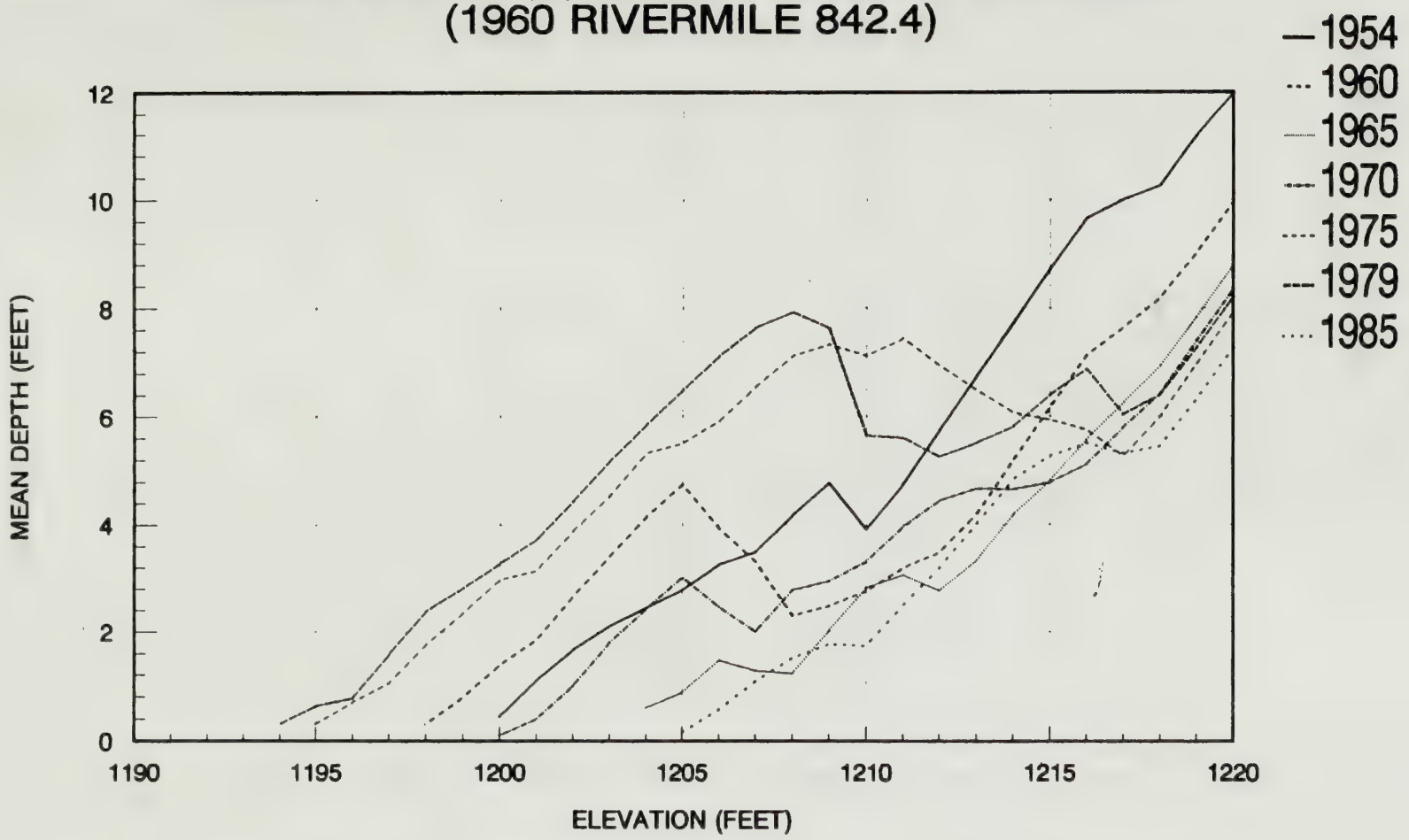
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 883.9

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 842.4)



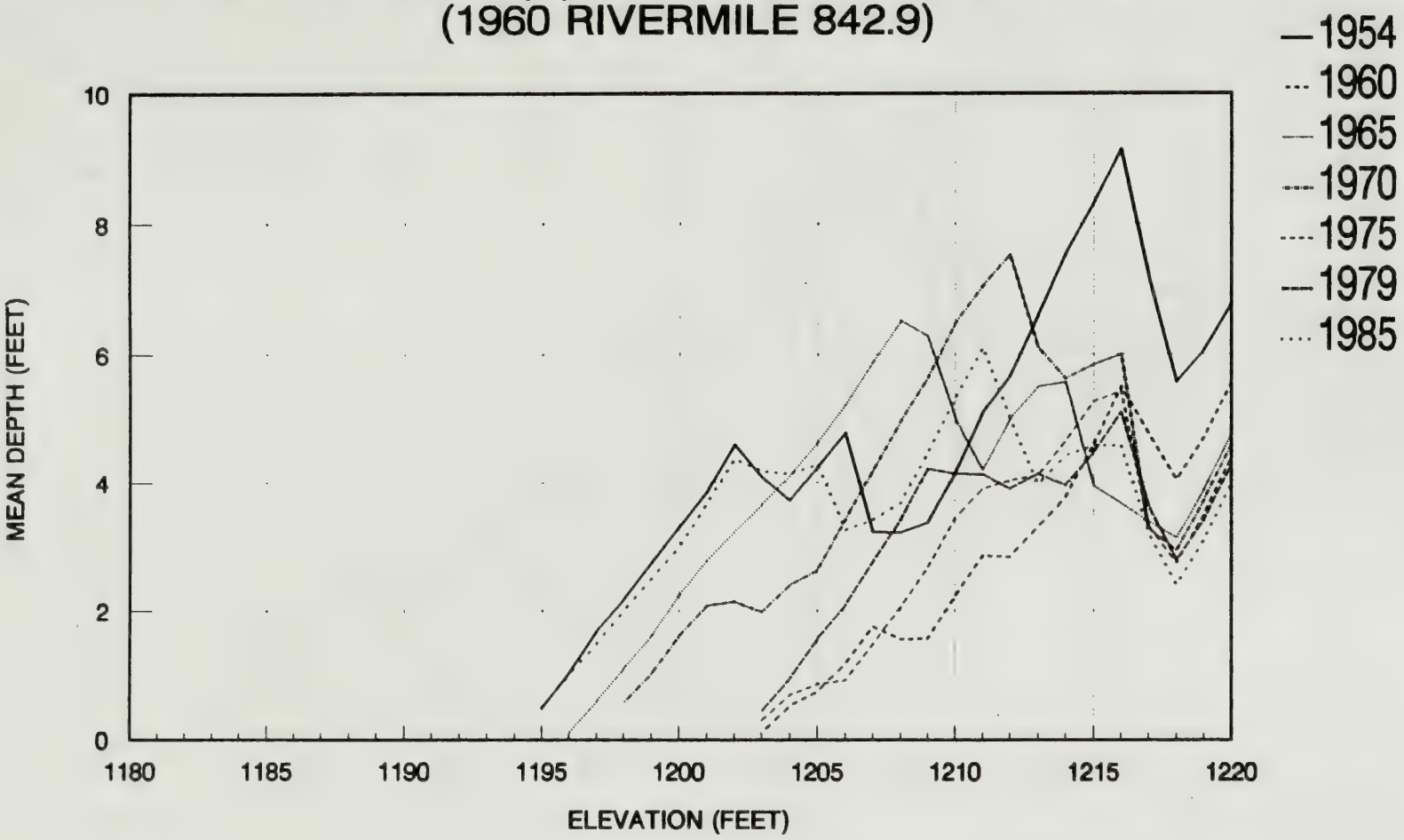
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 884.4

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 842.9)



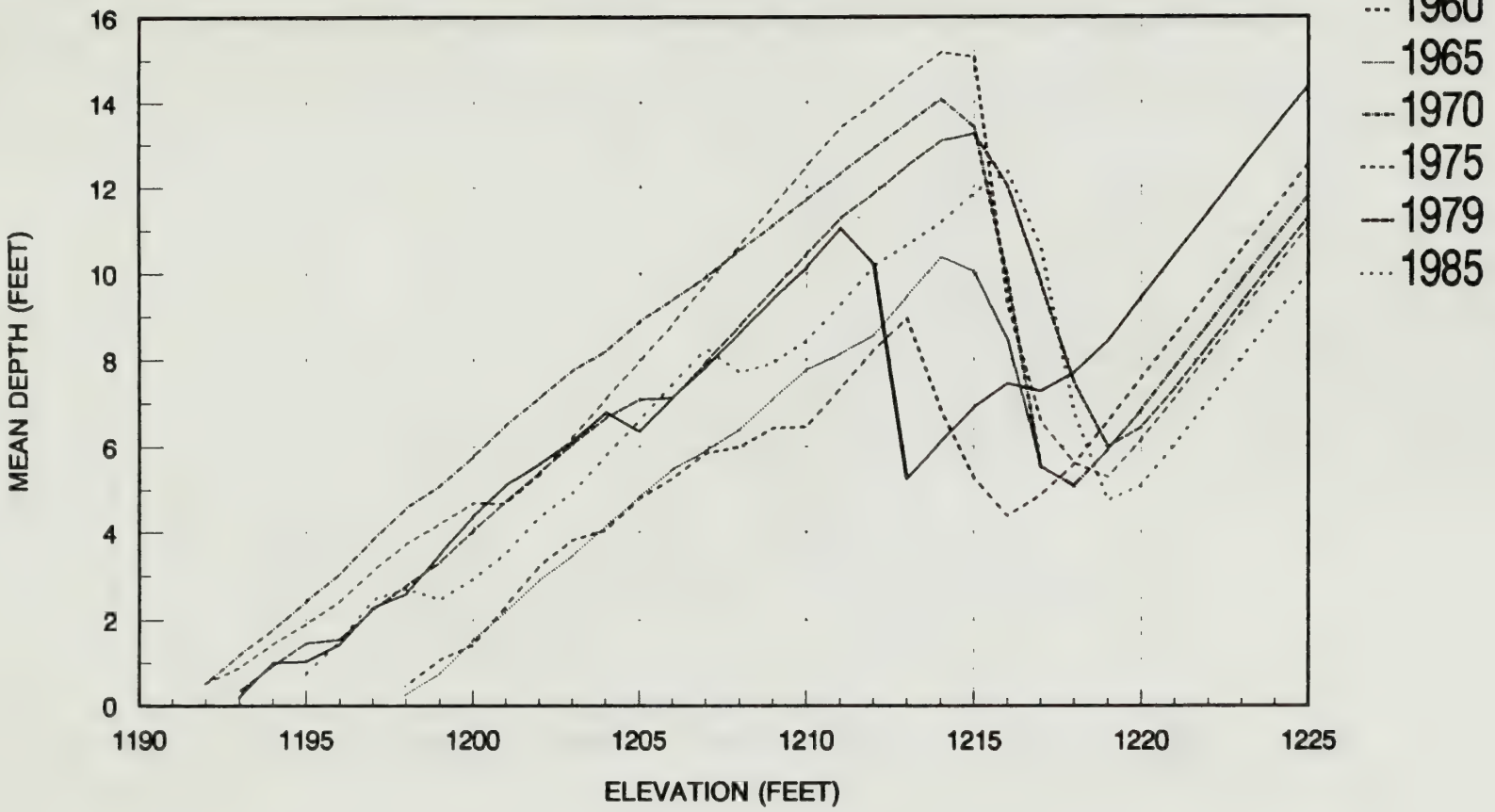
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 885.1

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 843.6)



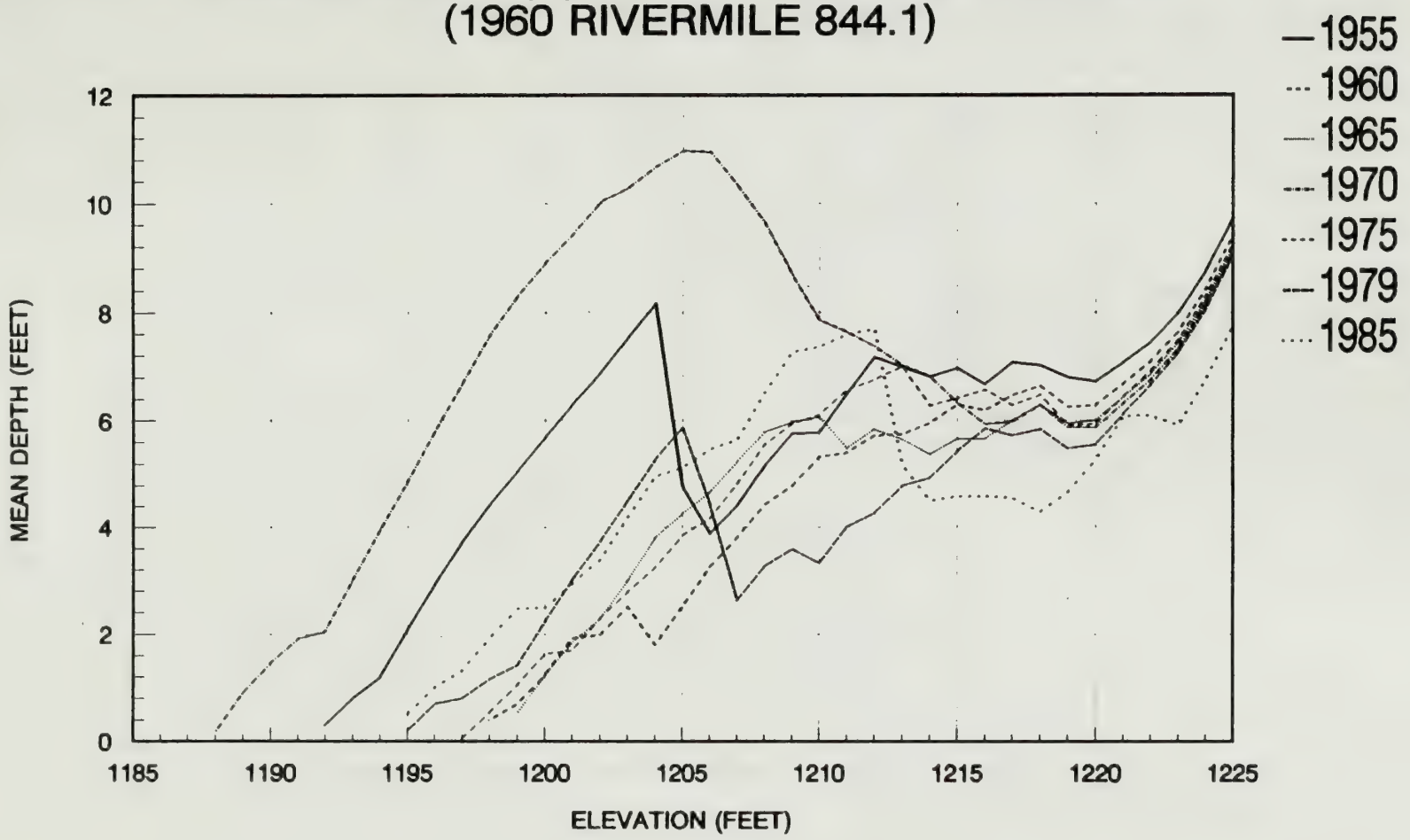
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 885.6

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 844.1)



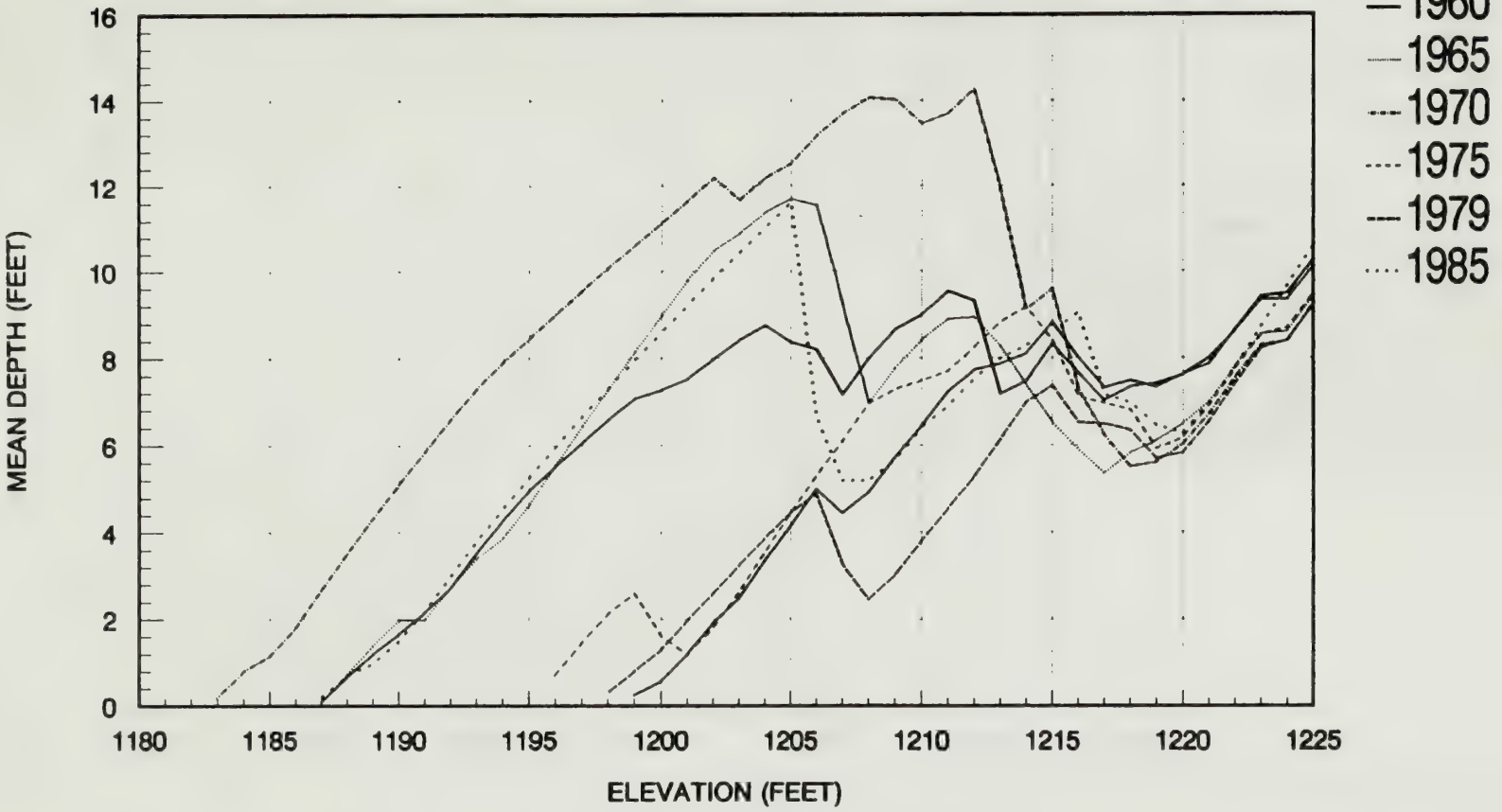
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER RANGE 886.8

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 845.2)



NIOBRARA RIVER AGGRADATION STUDY

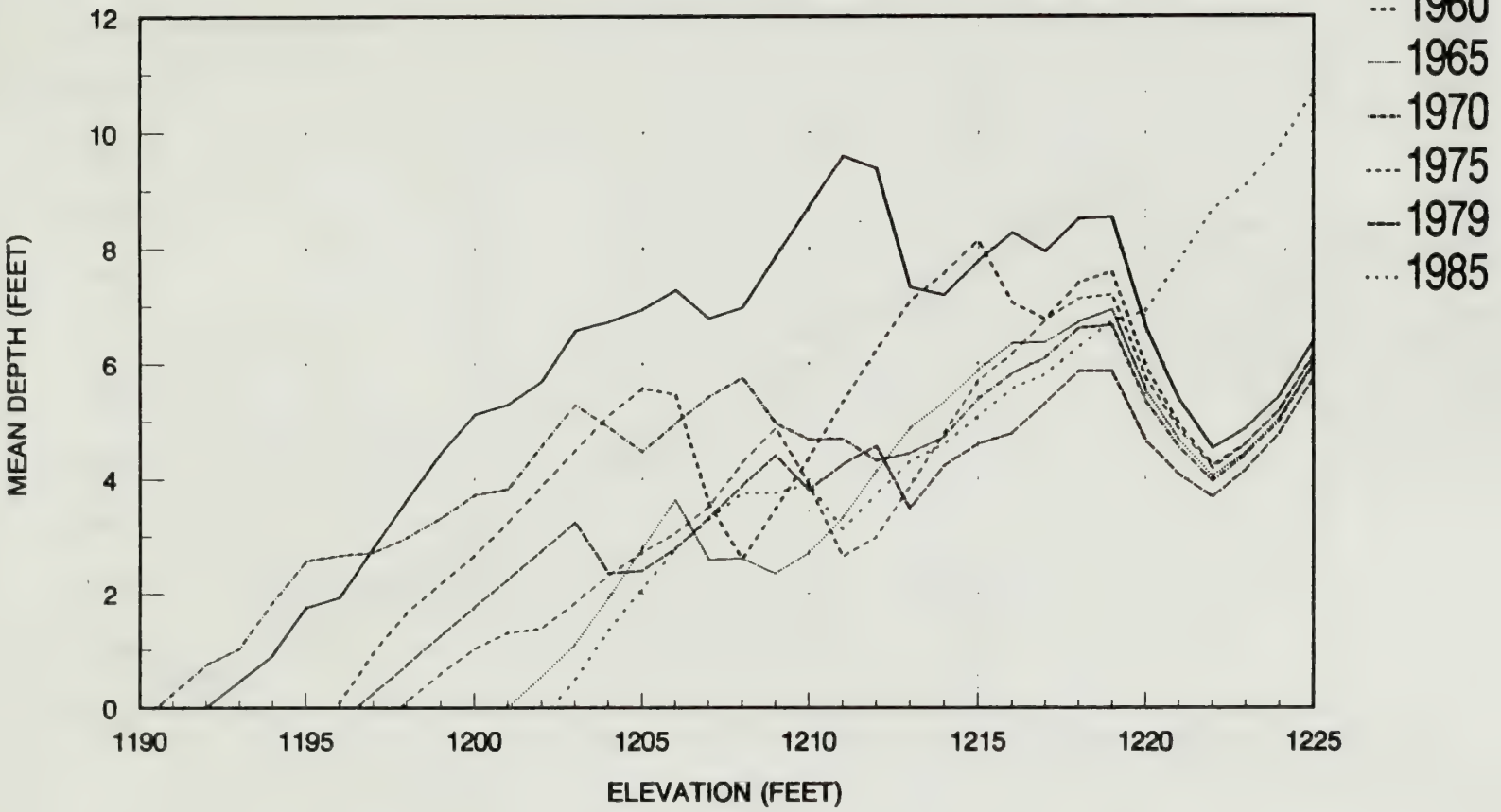
MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

Plate IV.95

MISSOURI RIVER RANGE 888.9

MEAN DEPTH (D) BELOW GIVEN ELEVATION
(1960 RIVERMILE 847.3)

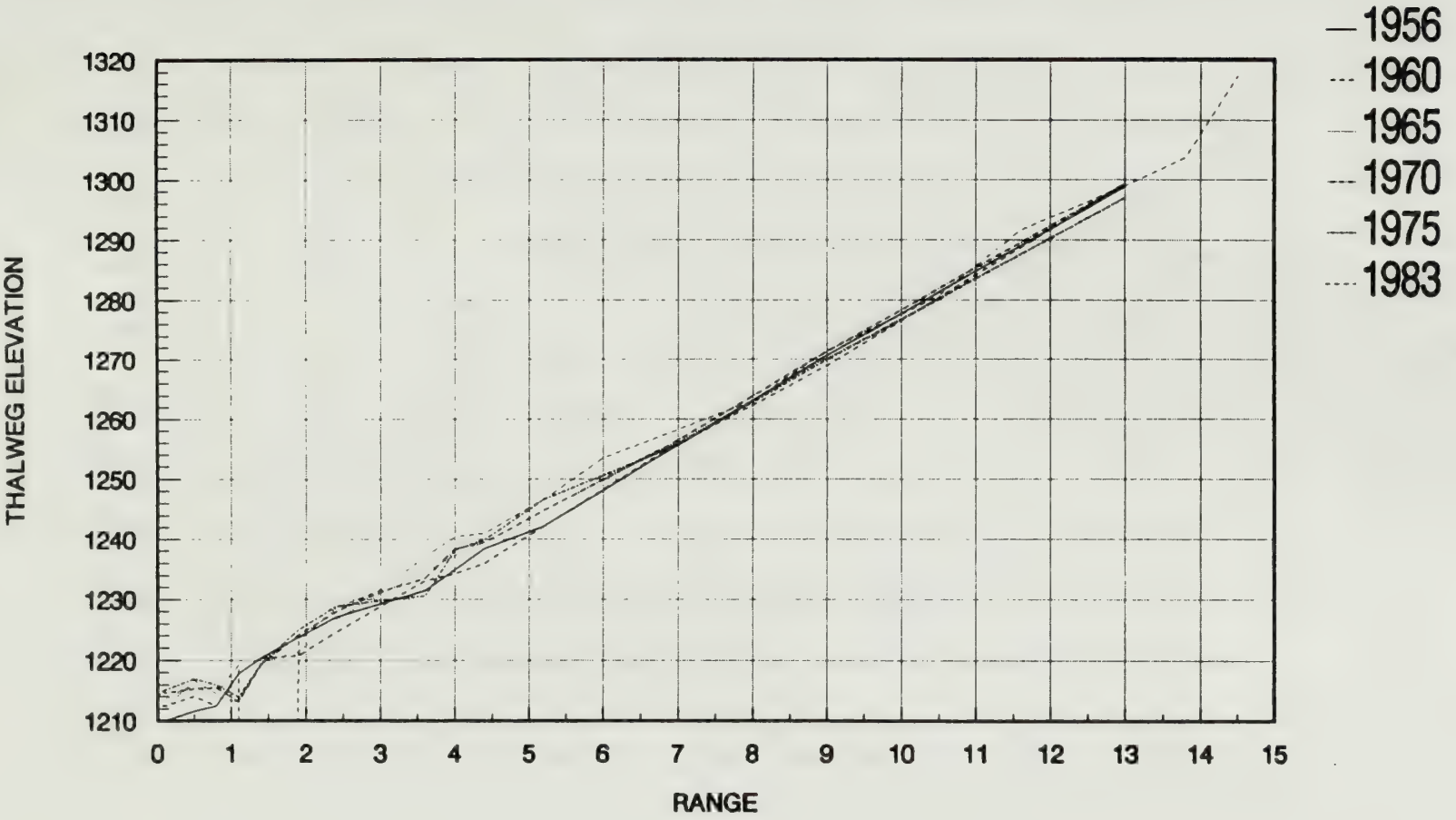


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC ELEMENTS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
THALWEG ELEVATION AT A GIVEN RANGE

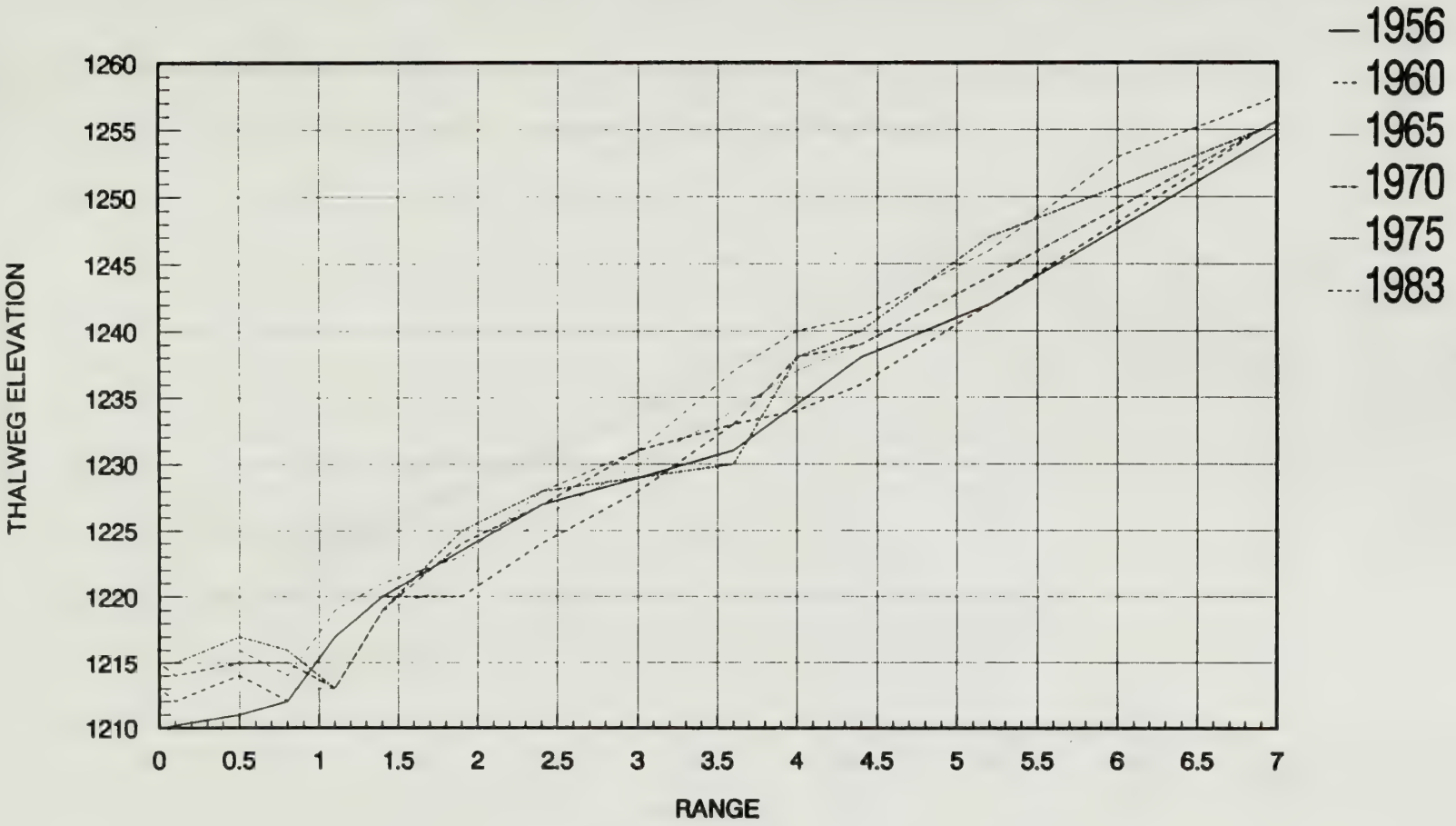


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
THALWEG ELEVATION

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
MAY 1992

THALWEG ELEVATION AT A GIVEN RANGE

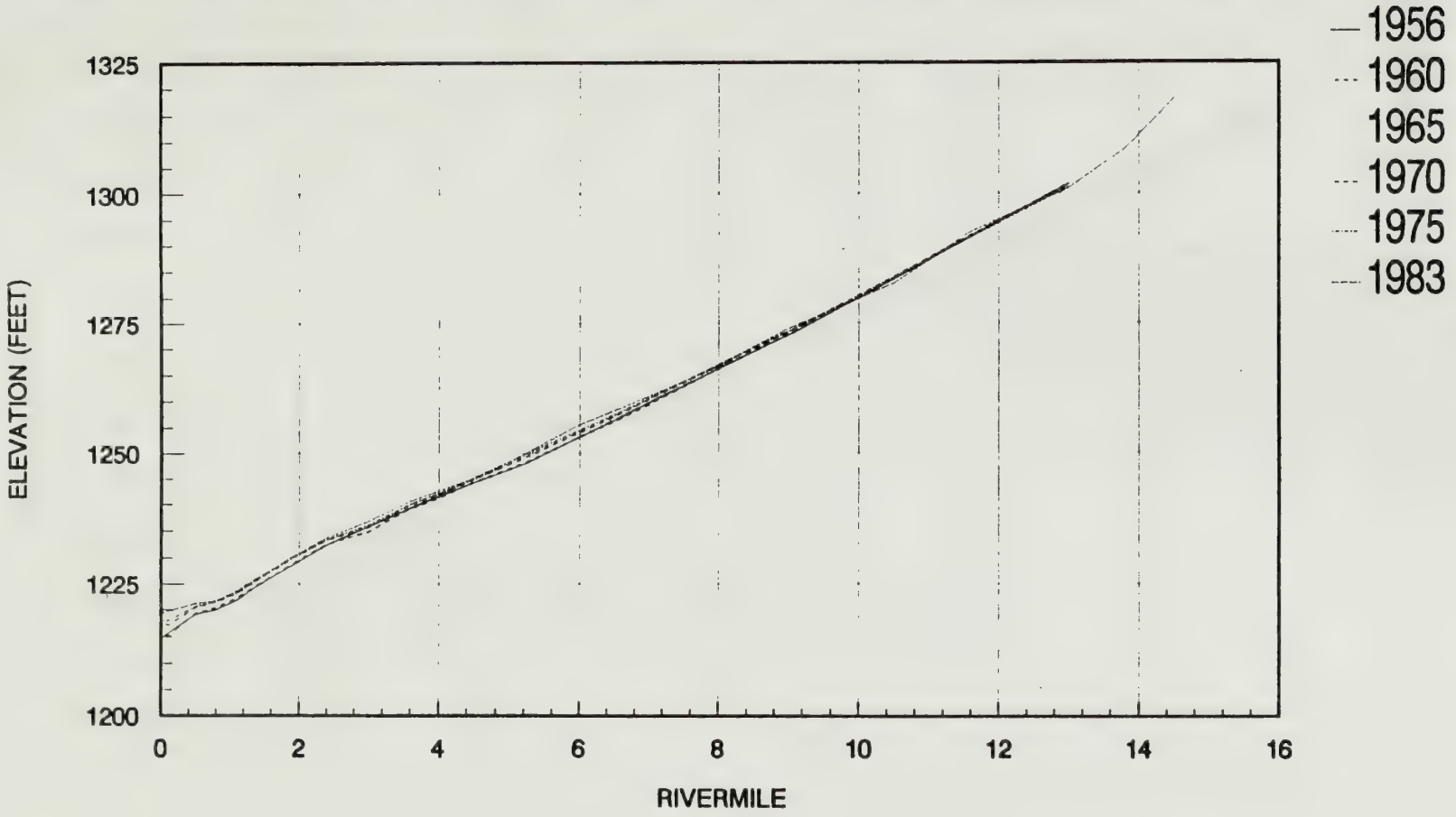


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
THALWEG ELEVATION

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
APRIL 1992

NIOBRARA RIVER
AVERAGE BED ELEVATION (E) AT COMMON REFERENCE PLANE



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC PARAMETERS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1991

NIOBRARA RIVER
AVERAGE BED ELEVATION (E) AT COMMON REFERENCE PLANE

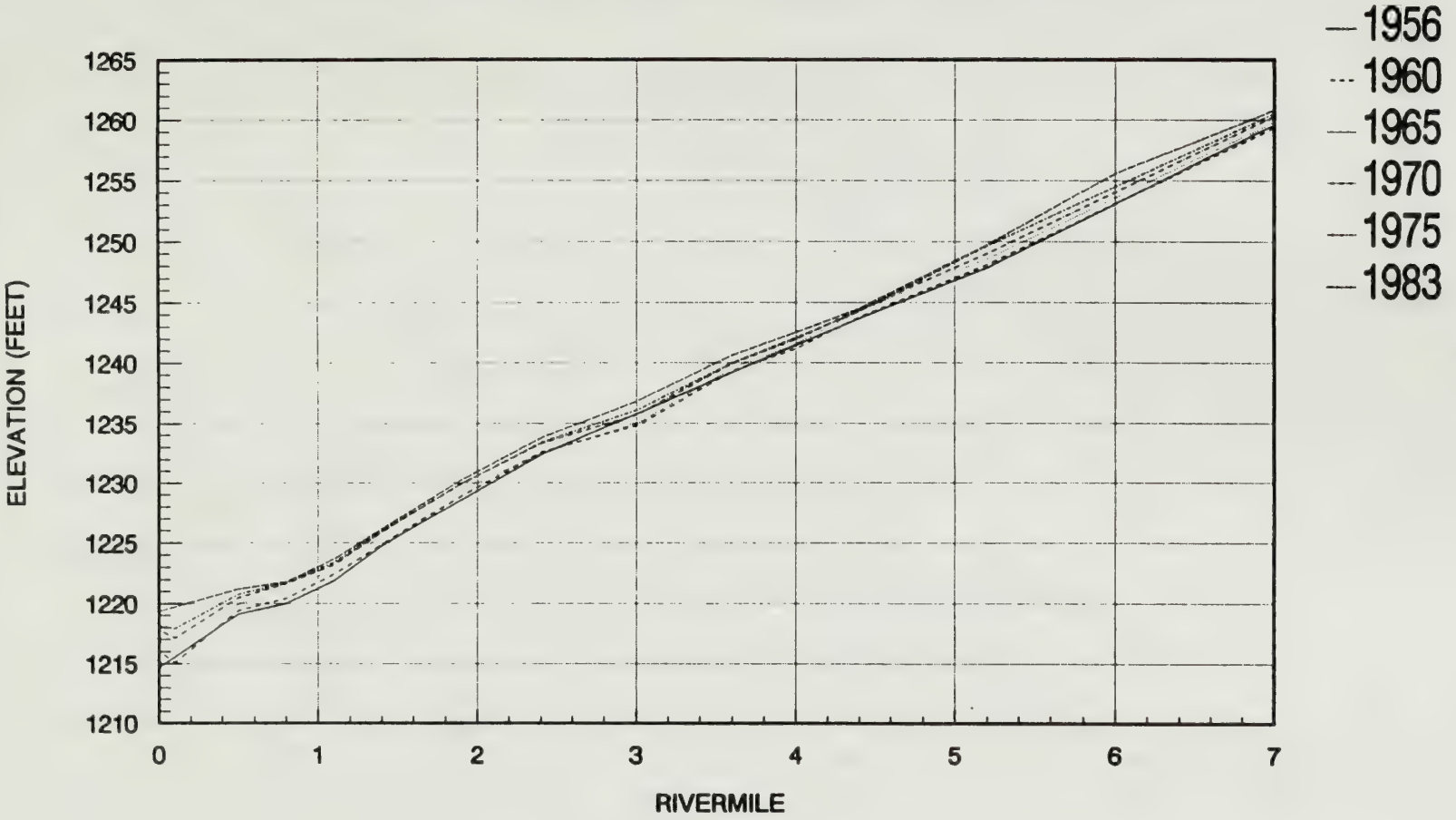


Plate IV.100

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC PARAMETERS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
APRIL 1992

NIOBRARA RIVER
TOP WIDTH (W) AT COMMON REFERENCE PLANE

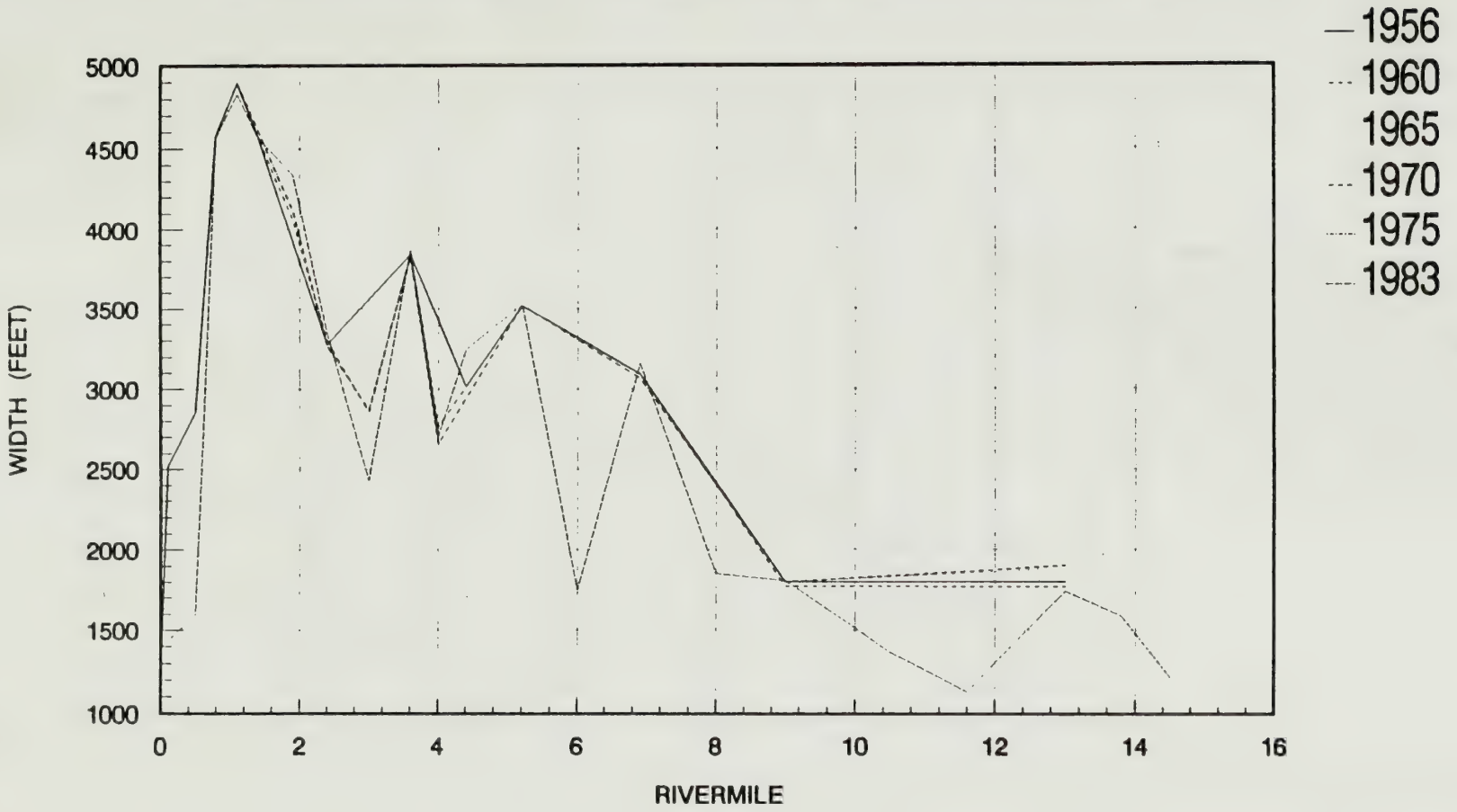


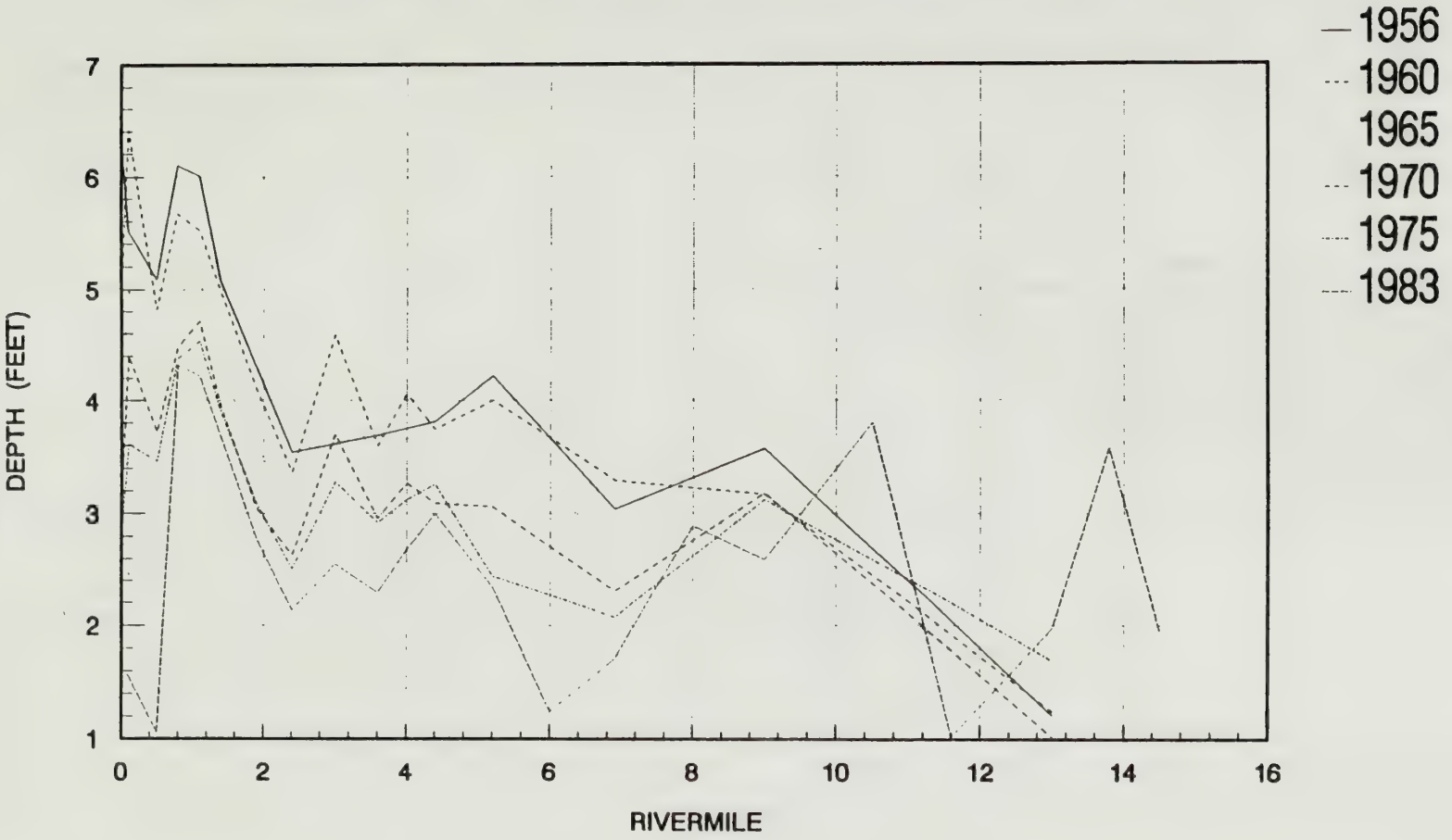
Plate IV.101

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC PARAMETERS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1991

NIOBRARA RIVER
DEPTH (D) AT COMMON REFERENCE PLANE

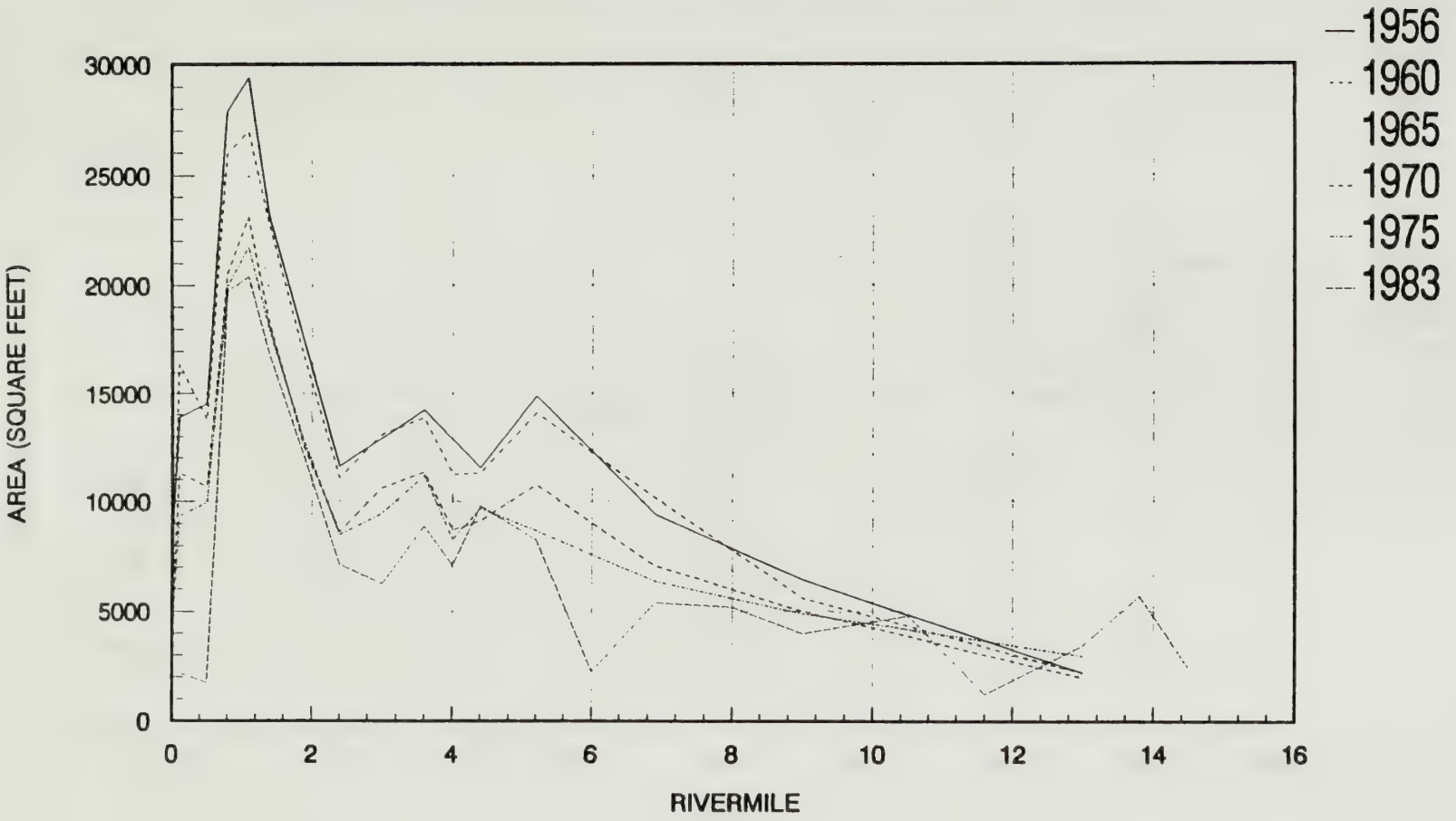


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC PARAMETERS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1991

NIOBRARA RIVER
AREA (A) AT COMMON REFERENCE PLANE

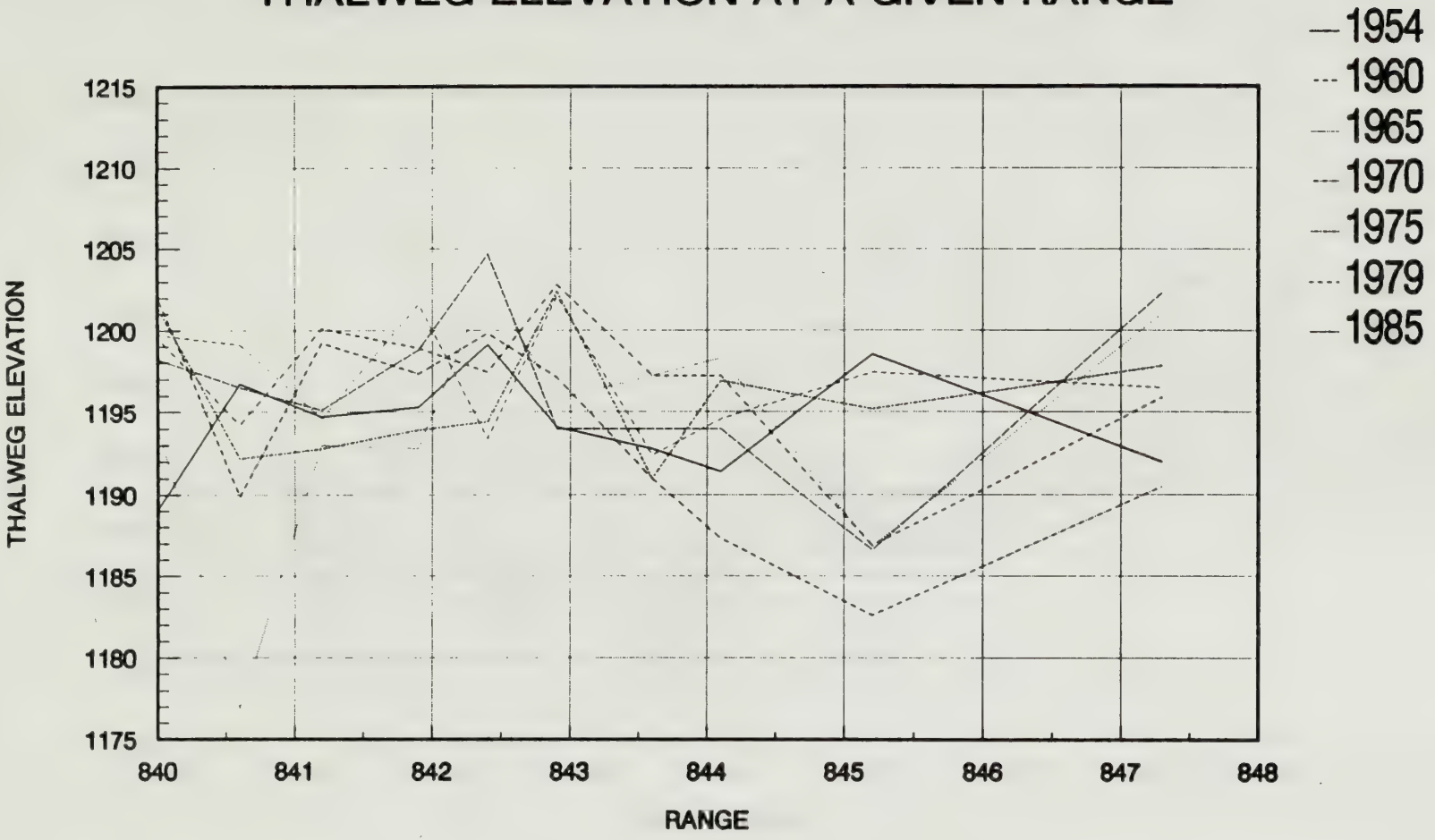


NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
HYDRAULIC PARAMETERS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1991

MISSOURI RIVER
THALWEG ELEVATION AT A GIVEN RANGE



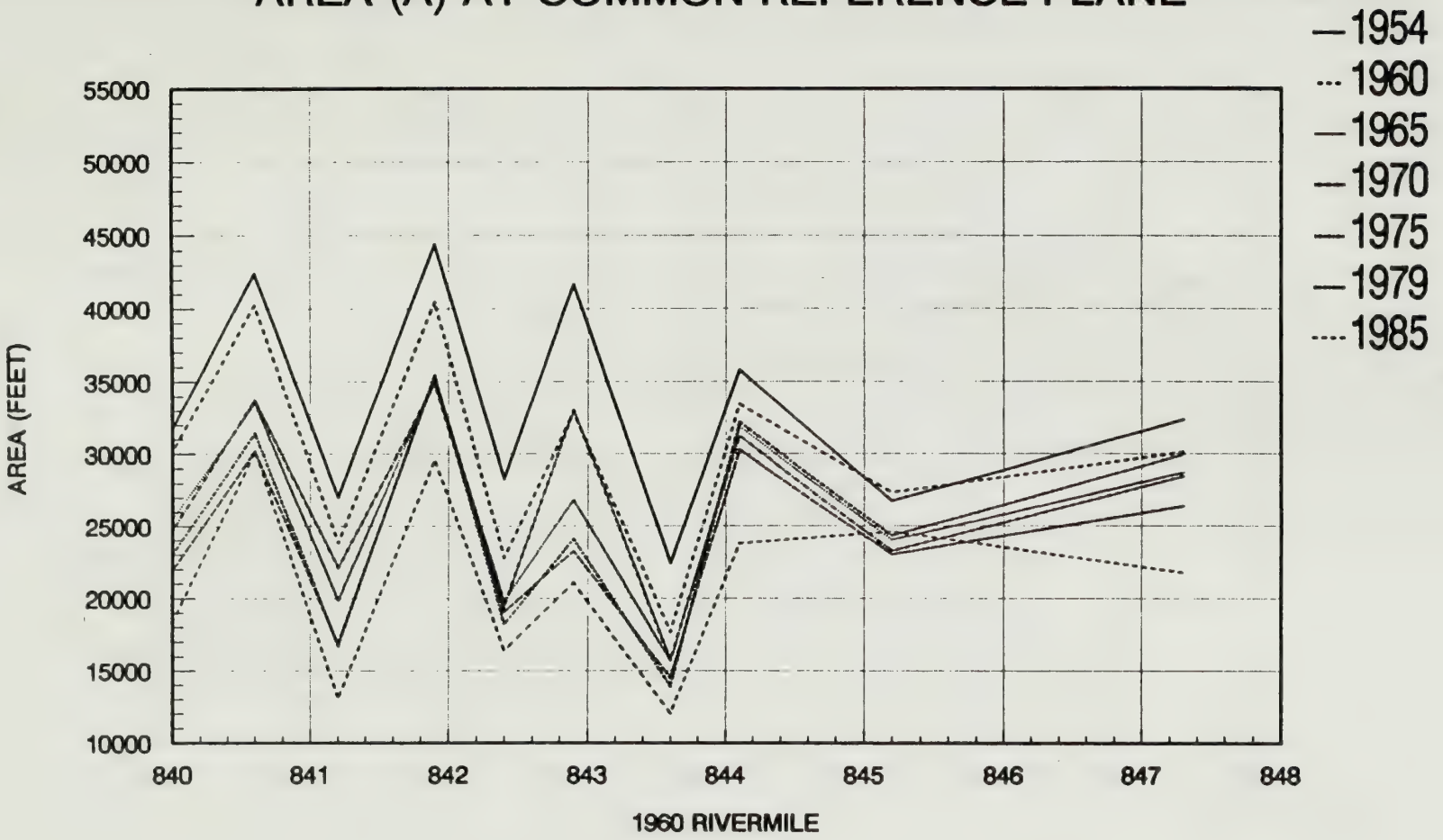
NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
THALWEG ELEVATION

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
MAY 1992

Plate IV.104

MISSOURI RIVER
AREA (A) AT COMMON REFERENCE PLANE

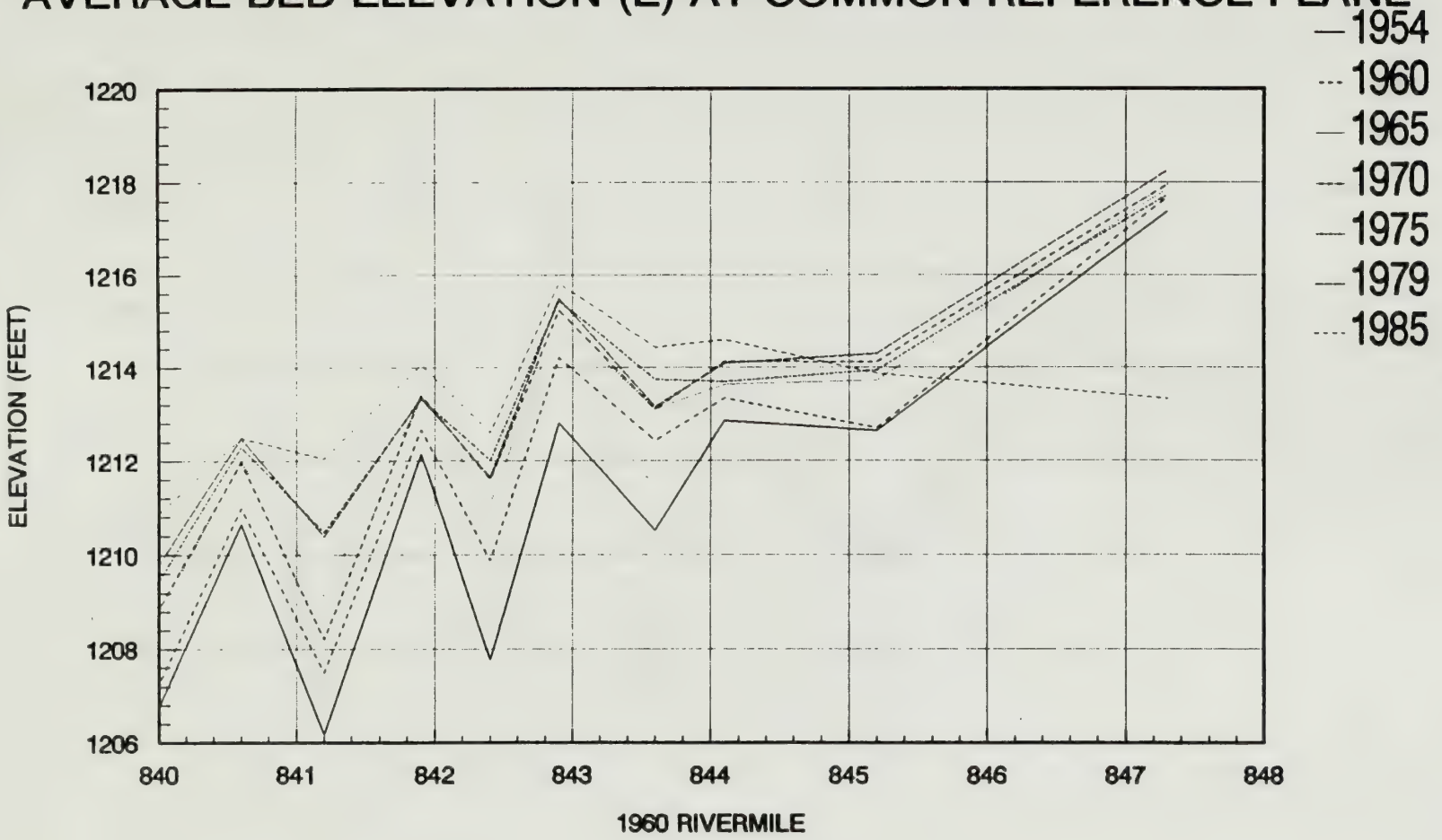


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC PARAMETERS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
APRIL 1992

MISSOURI RIVER
AVERAGE BED ELEVATION (E) AT COMMON REFERENCE PLANE

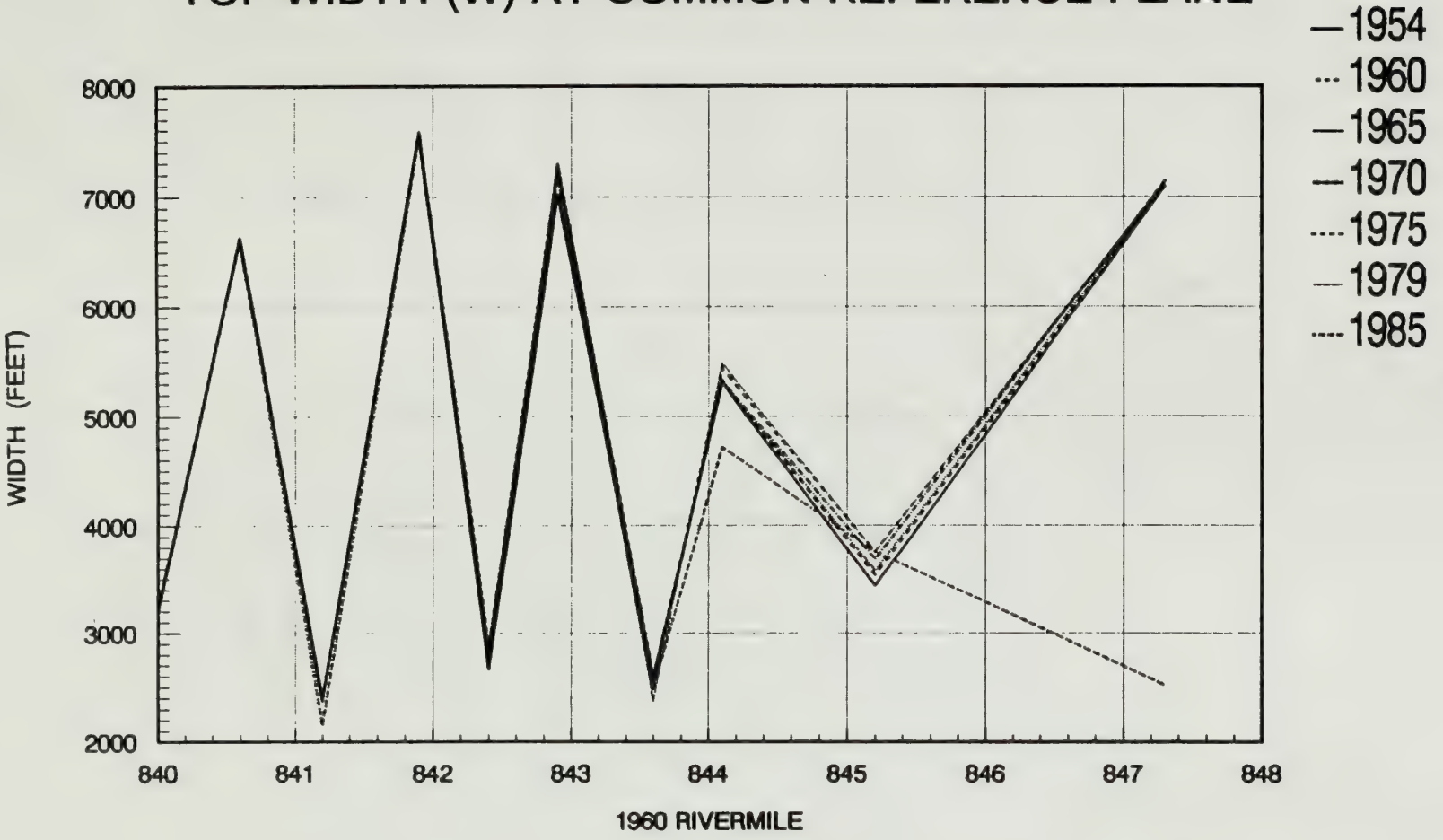


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC PARAMETERS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
APRIL 1992

MISSOURI RIVER
TOP WIDTH (W) AT COMMON REFERENCE PLANE

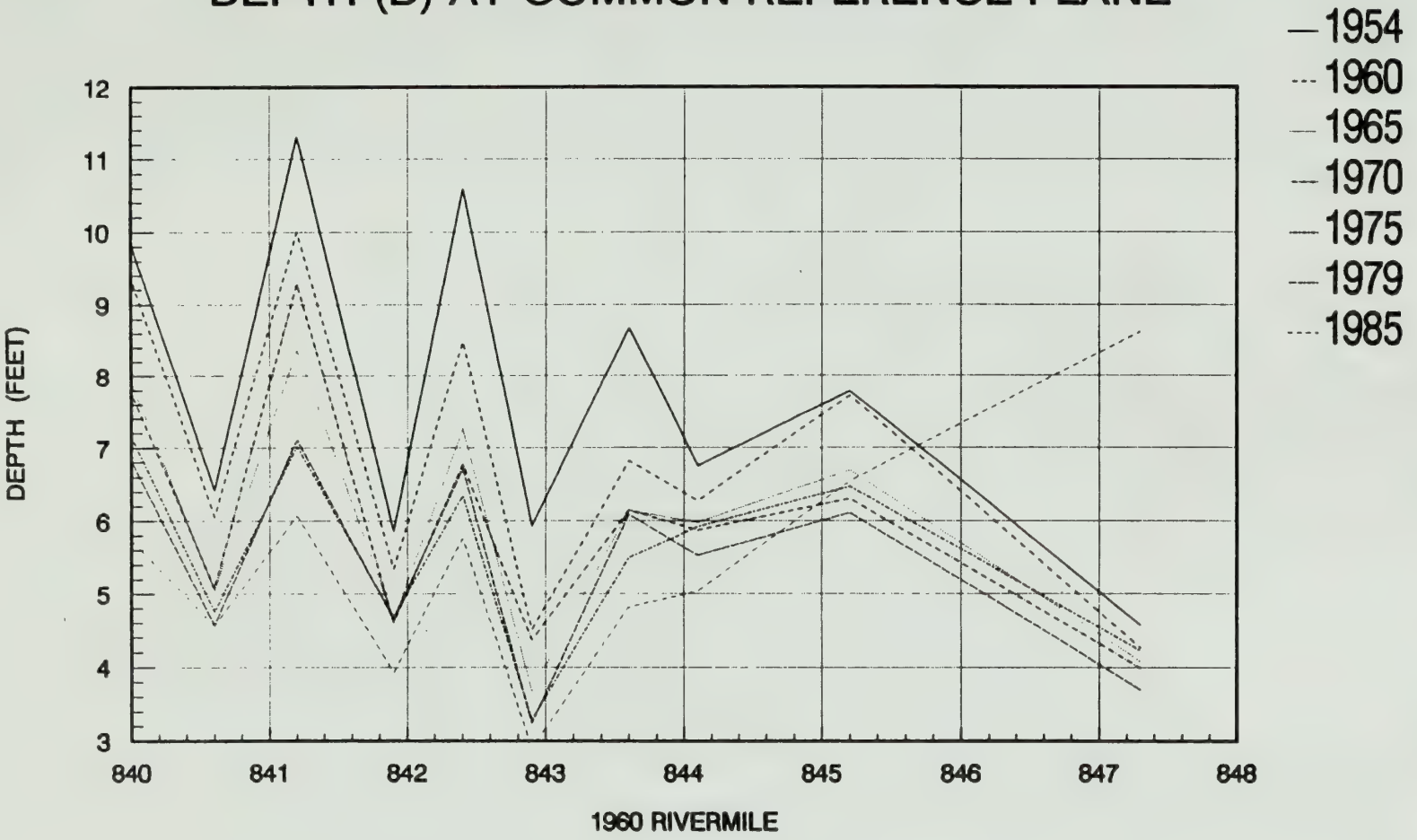


NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC PARAMETERS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
APRIL 1992

MISSOURI RIVER
DEPTH (D) AT COMMON REFERENCE PLANE



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
HYDRAULIC PARAMETERS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
APRIL 1992

APPENDIX V

BED SEDIMENT GRADATIONS

NIOBRARA RIVER

CHANNEL BED MATERIAL - 35% COARSER GRAIN SIZE

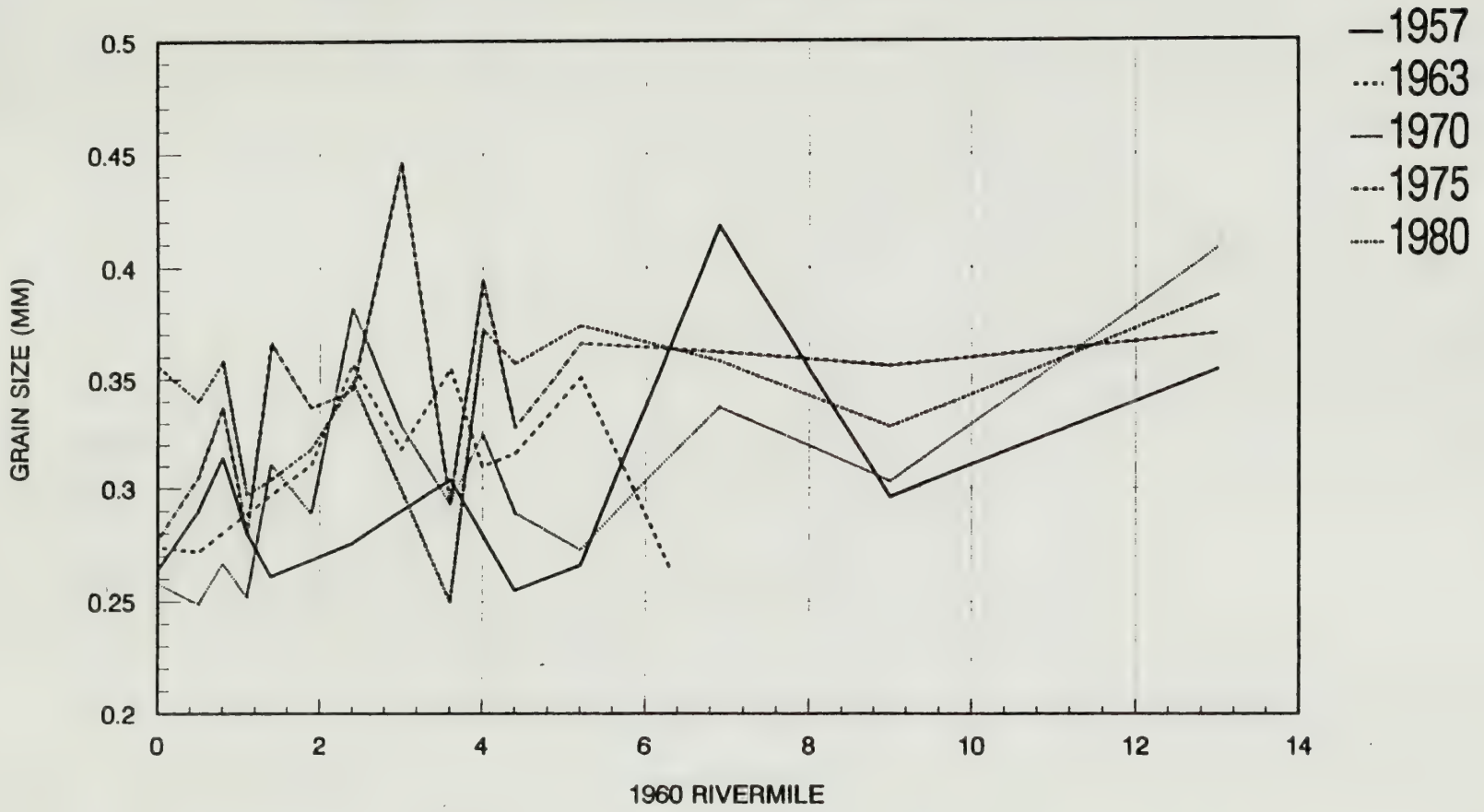


Plate V.2

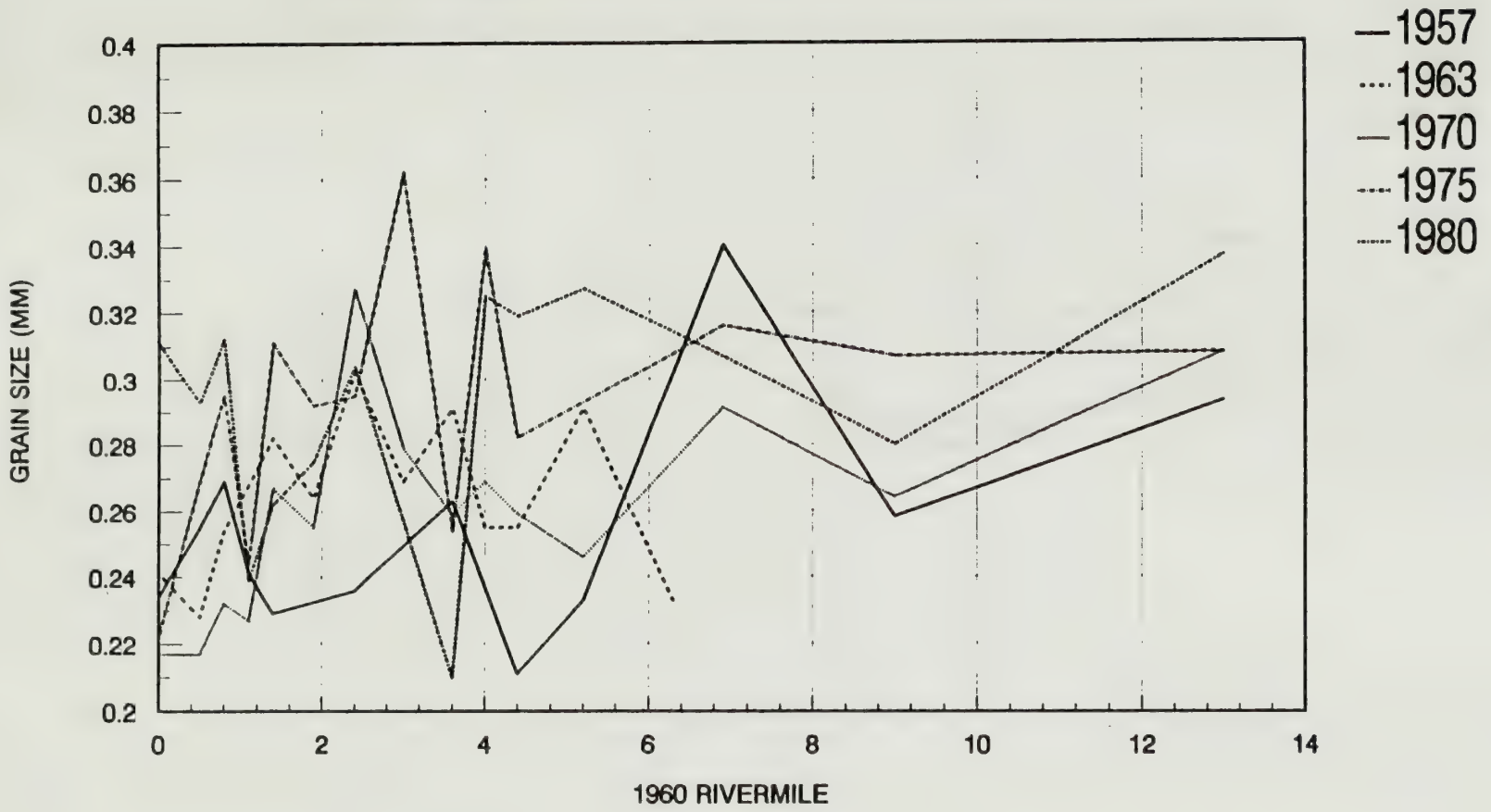
NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL BED MATERIALS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER

CHANNEL BED MATERIAL - 50% COARSER GRAIN SIZE



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL BED MATERIALS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

Plate V.3

NIOBRARA RIVER

CHANNEL BED MATERIAL - 65% COARSER GRAIN SIZE

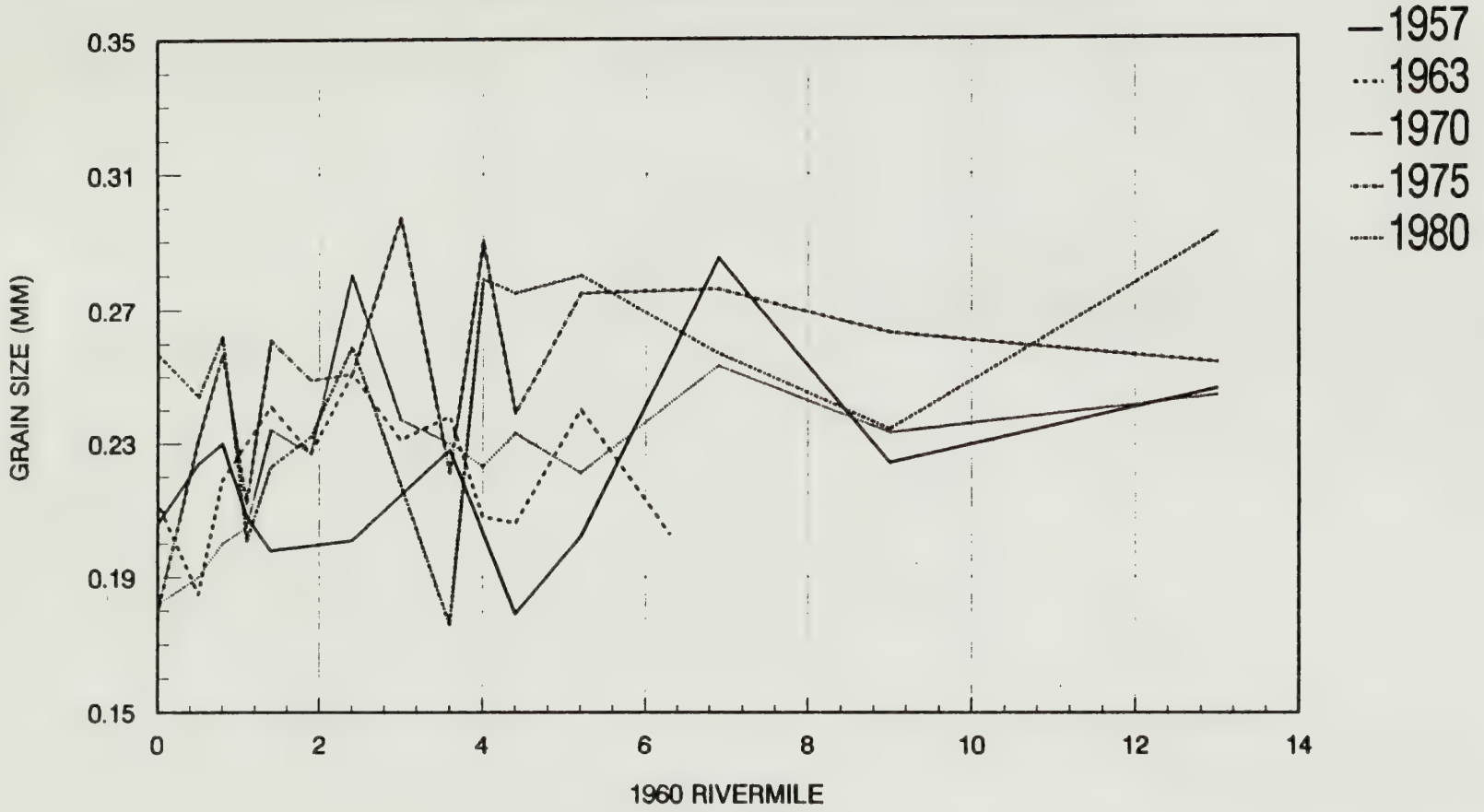


Plate V.4

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL BED MATERIALS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER

CHANNEL BED MATERIAL - 90% COARSER GRAIN SIZE

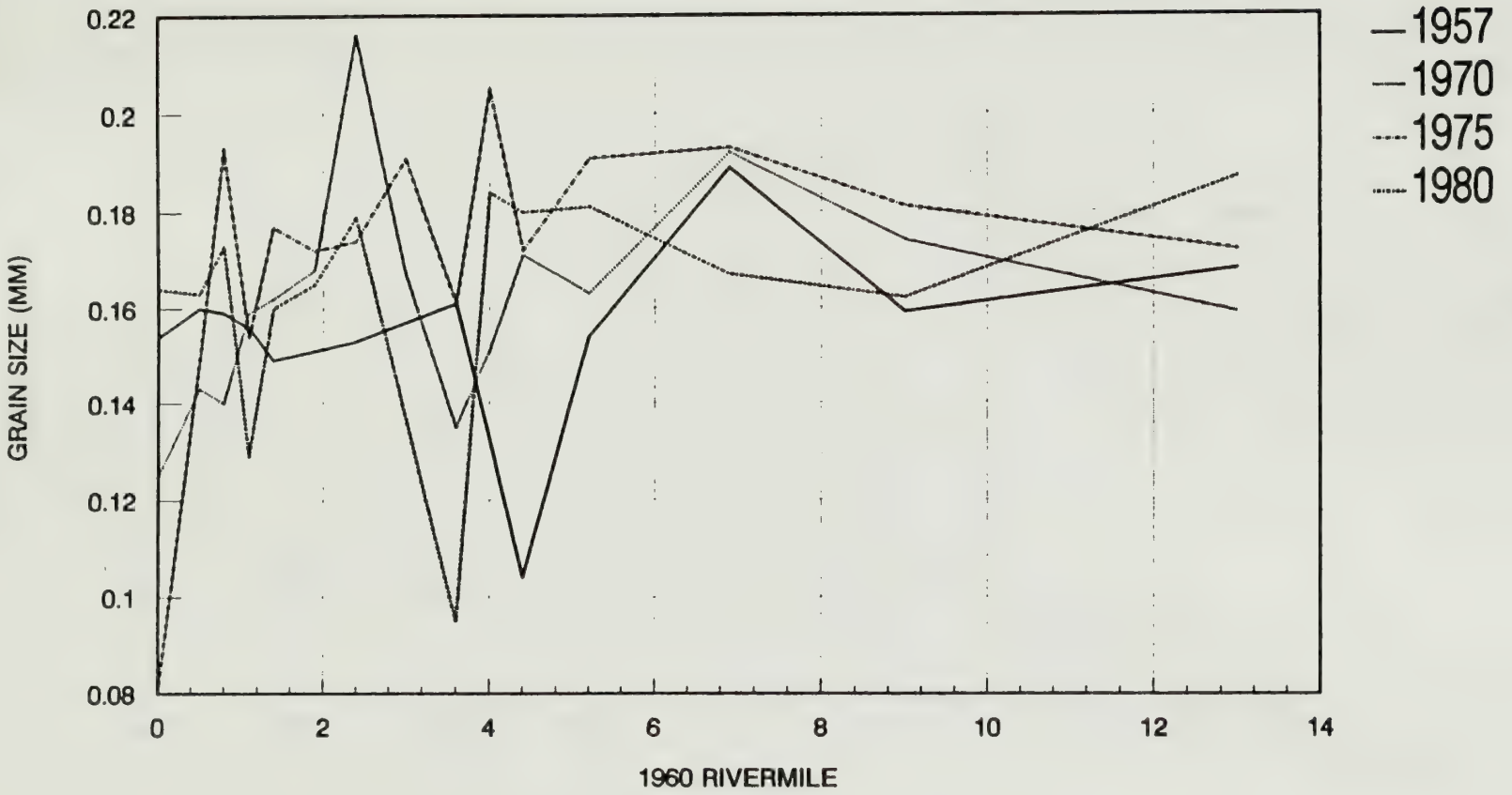


Plate V.5

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
CHANNEL BED MATERIALS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER

CHANNEL BED MATERIAL - 10% COARSER GRAIN SIZE

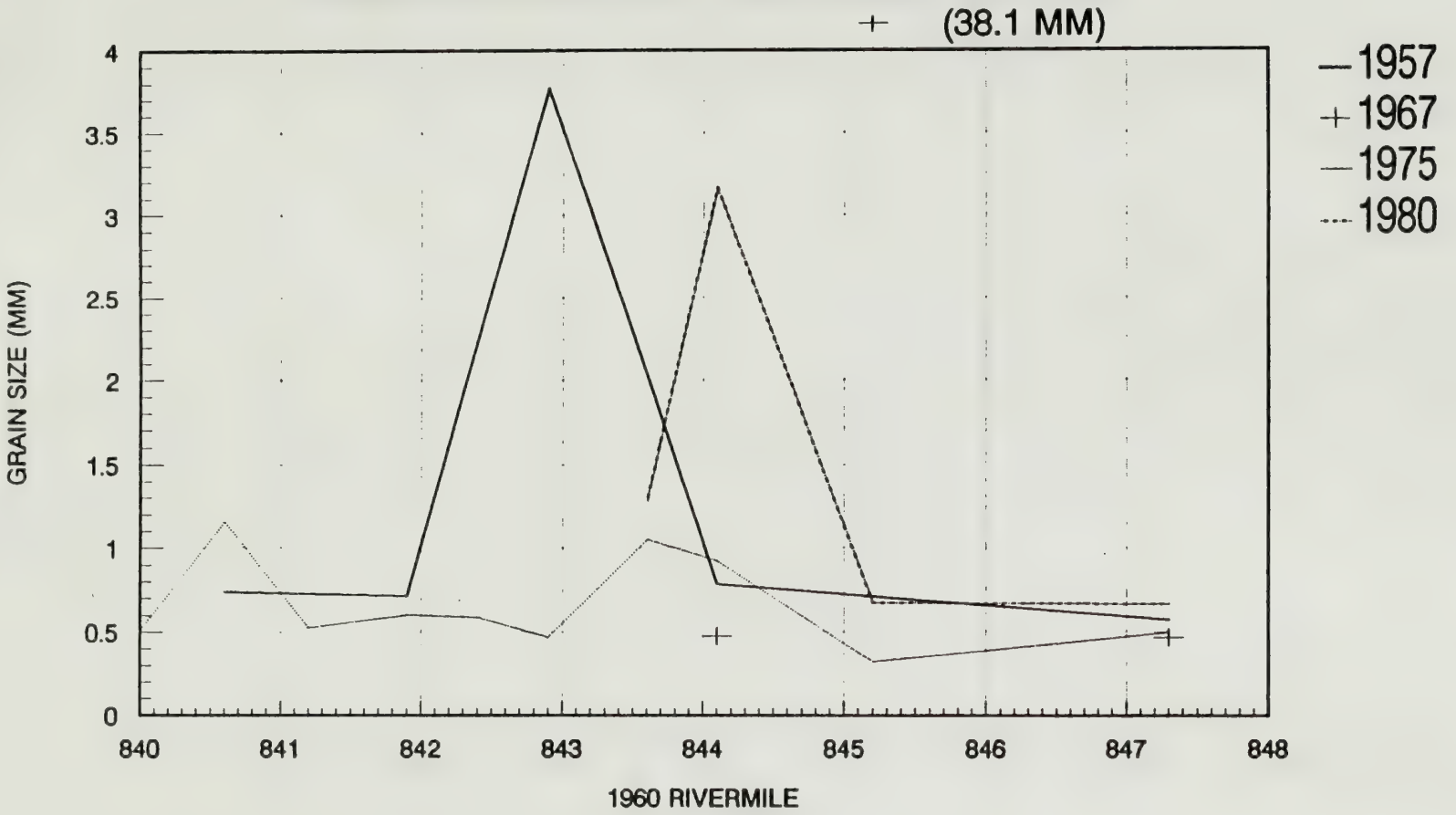


Plate V.6

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL BED MATERIALS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER

CHANNEL BED MATERIAL - 35% COARSER GRAIN SIZE

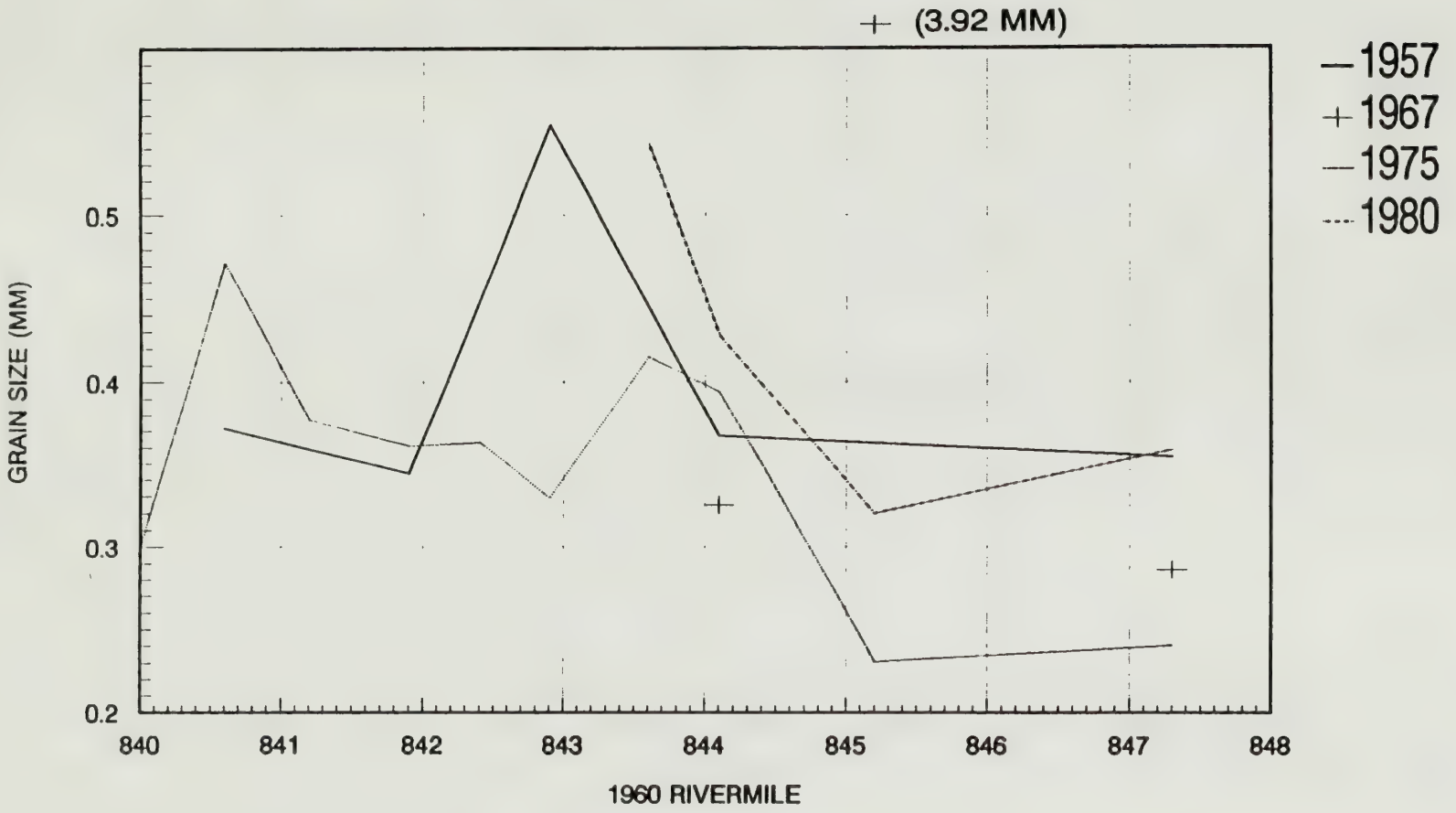


Plate V.7

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL BED MATERIALS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER

CHANNEL BED MATERIAL - 50% COARSER GRAIN SIZE

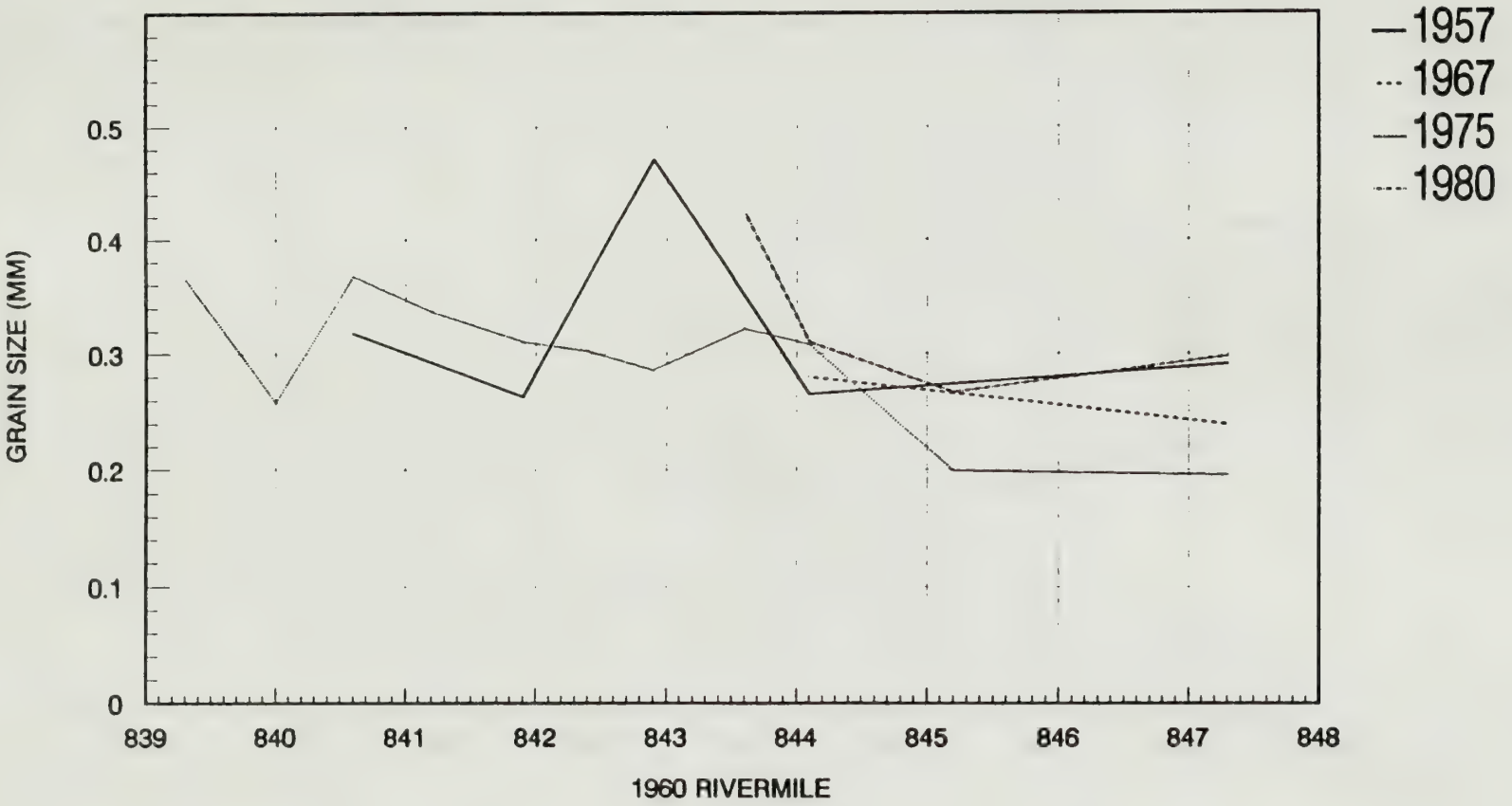


Plate V.8

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL BED MATERIALS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER

CHANNEL BED MATERIAL - 65% COARSER GRAIN SIZE

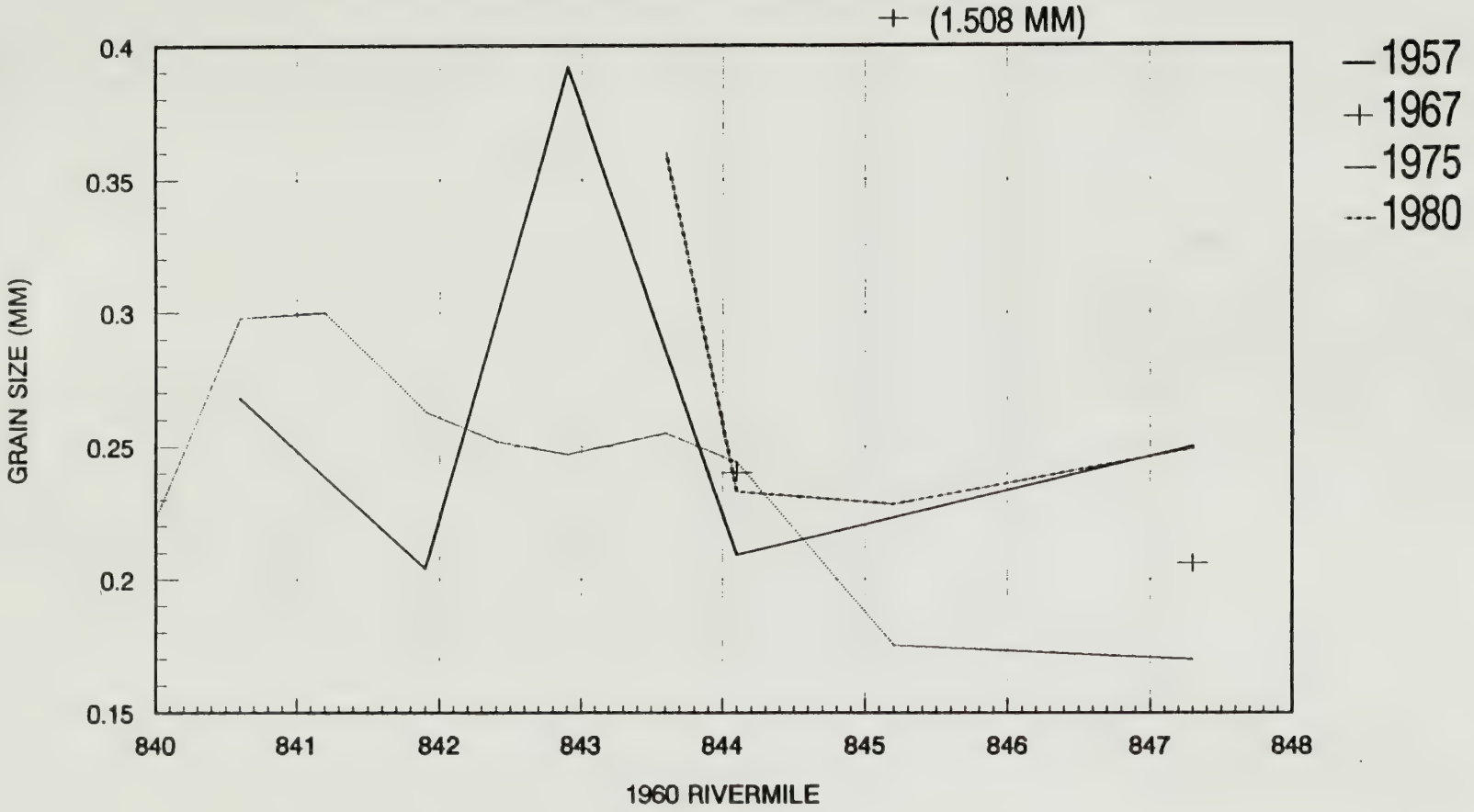


Plate V.9

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL BED MATERIALS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER

CHANNEL BED MATERIAL - 90% COARSER GRAIN SIZE

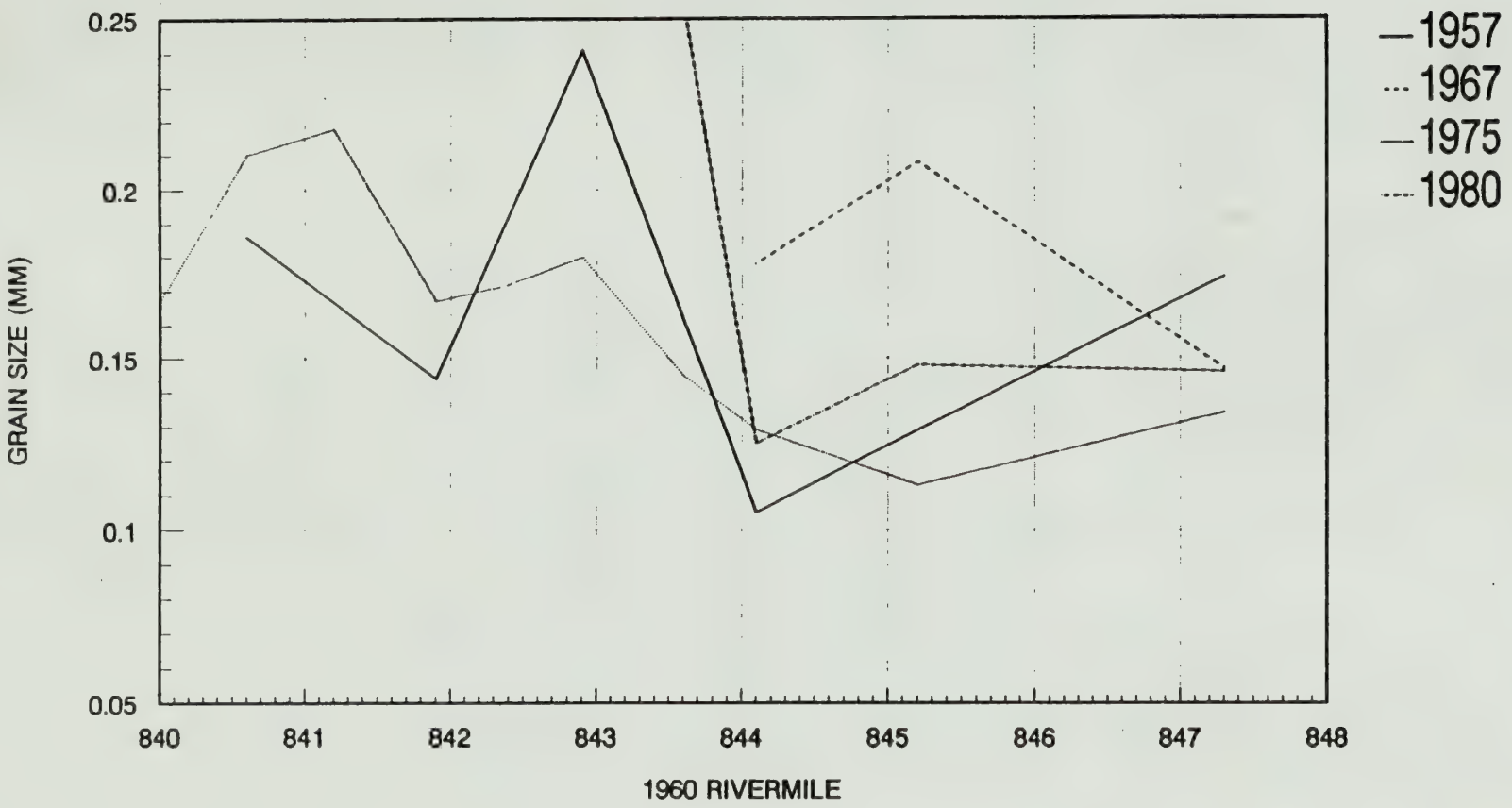


Plate V.10

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
CHANNEL BED MATERIALS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

APPENDIX VI

GROUNDWATER PIEZOMETER HYDROGRAPHS

Table VI.1. Niobrara River Sediment Plots.

Year	Percent Finer	Grain Size (mm) Range															
		0	0.5	0.8	1.1	1.4	1.9	2.4	3.0	3.6	4.0	4.4	5.2	6.3	6.9	9.0	13.0
1957	D10	0.154	0.16	0.159	0.156	0.149		0.153		0.161		0.104	0.154		0.189	0.159	0.168
	D35	0.206	0.224	0.23	0.208	0.198		0.201		0.228		0.179	0.202		0.285	0.224	0.246
	D50	0.234	0.255	0.269	0.241	0.229		0.236		0.263		0.211	0.233		0.34	0.258	0.293
	D65	0.264	0.29	0.314	0.28	0.261		0.276		0.304		0.255	0.266		0.418	0.296	0.354
	D90	0.369	0.4	0.412	0.413	0.414		0.415		0.409		0.392	0.384		0.99	0.418	0.567
1963	D10	0.127	0.039	0.104		0.163	0.162	0.166	0.161	0.161	0.123	0.064	0.161	0.153			
	D35	0.212	0.185	0.219		0.241	0.227	0.251	0.231	0.238	0.208	0.206	0.24	0.203			
	D50	0.241	0.228	0.254		0.282	0.264	0.302	0.269	0.291	0.255	0.255	0.291	0.233			
	D65	0.274	0.272	0		0	0.311	0.357	0.318	0.355	0.31	0.316	0.351	0.265			
	D90	0.386	0.406	0.41		0.48	0.457	0.538	0.496	0.587	0.428	0.483	0.558	0.376			
1970	D10	0.125	0.143	0.14	0.159	0.162	0.168	0.216	0.167	0.135	0.151	0.171	0.163		0.192	0.174	0.159
	D35	0.182	0.19	0.2	0.205	0.234	0.227	0.28	0.237	0.23	0.223	0.233	0.221		0.253	0.233	0.244
	D50	0.217	0.217	0.232	0.227	0.267	0.255	0.327	0.279	0.259	0.269	0.259	0.246		0.291	0.264	0.308
	D65	0.258	0.249	0.267	0.252	0.311	0.289	0.382	0.329	0.293	0.325	0.289	0.273		0.337	0.303	0.408
	D90	0.384	0.329	0.385	0.337	0.486	0.422	0.69	0.507	0.431	0.658	0.406	0.385		0.596	0.462	1.493
1975	D10	0.081	0.149	0.193	0.154	0.177	0.172	0.174	0.191	0.161	0.205	0.172	0.191		0.193	0.181	0.172
	D35	0.18	0.231	0.257	0.212	0.261	0.249	0.251	0.297	0.221	0.29	0.239	0.275		0.276	0.263	0.254
	D50	0.222	0.269	0.295	0.244	0.311	0.292	0.295	0.362	0.254	0.339	0.282	0		0.316	0.307	0.308
	D65	0.277	0.305	0.337	0.28	0.366	0.337	0.345	0.446	0.293	0.394	0.328	0.366		0.362	0.356	0.37
	D90	0.439	0.417	0.42	0.392	0.587	0.455	0.586	1.062	0.403	0.549	0.45	0.534		0.489	0.514	0.736
1983	D10	0.164	0.163	0.173	0.129	0.16	0.165	0.179		0.095	0.184	0.18	0.181		0.167	0.162	0.187
	D35	0.257	0.244	0.262	0.201	0.223	0.232	0.259		0.176	0.279	0.275	0.28		0.257	0.234	0.292
	D50	0.311	0.293	0.312	0.239	0.262	0.275	0.304		0.21	0.325	0.319	0.327		0.307	0.28	0.337
	D65	0.356	0.34	0.358	0.297	0.304	0.318	0.349		0.25	0.372	0.357	0.374		0.358	0.328	0.387
	D90	0.509	0.47	0.509	0.43	0.399	0.448	0.439		0.368	0.601	0.475	0.634		0.557	0.497	0.874

Table VI.2. Missouri River Sediment Plots.

Year	Percent Finer	Grain Size (mm)										
		1960 River Mile										
		880.7	881.4	882.0	882.6	883.3	883.9	884.4	885.1	885.6	886.8	888.9
1957	D10			0.186		0.144		0.241		0.105		0.174
	D35			0.268		0.204		0.392		0.209		0.25
	D50			0.318		0.263		0.471		0.265		0.291
	D65			0.372		0.344		0.554		0.367		0.354
	D90			0.741		0.717		3.772		0.786		0.572
1967	D10									0.178	0.208	0.147
	D35									0.24	1.508	0.206
	D50									0.28	2.625	0.239
	D65									0.325	3.92	0.286
	D90									0.475	38.1	0.466
1975	D10	0.239	0.167	0.21	0.218	0.167	0.172	0.18	0.145	0.129	0.113	0.134
	D35	0.32	0.223	0.298	0.3	0.263	0.252	0.247	0.255	0.244	0.175	0.17
	D50	0.366	0.258	0.368	0.337	0.311	0.303	0.286	0.322	0.308	0.199	0.196
	D65	0.449	0.3	0.472	0.377	0.361	0.363	0.329	0.415	0.394	0.231	0.241
	D90	0.99	0.51	1.157	0.526	0.601	0.59	0.469	1.052	0.923	0.32	0.496
1980	D10								0.254	0.125	0.148	0.146
	D35								0.36	0.233	0.228	0.249
	D50								0.423	0.31	0.267	0.298
	D65								0.543	0.428	0.32	0.358
	D90								1.275	3.166	0.673	0.666

NIOBRARA RIVER

WELL NUMBER, NIOBRARA TOWNSITE # 01

GROUNDWATER PIEZOMETER HYDROGRAPH

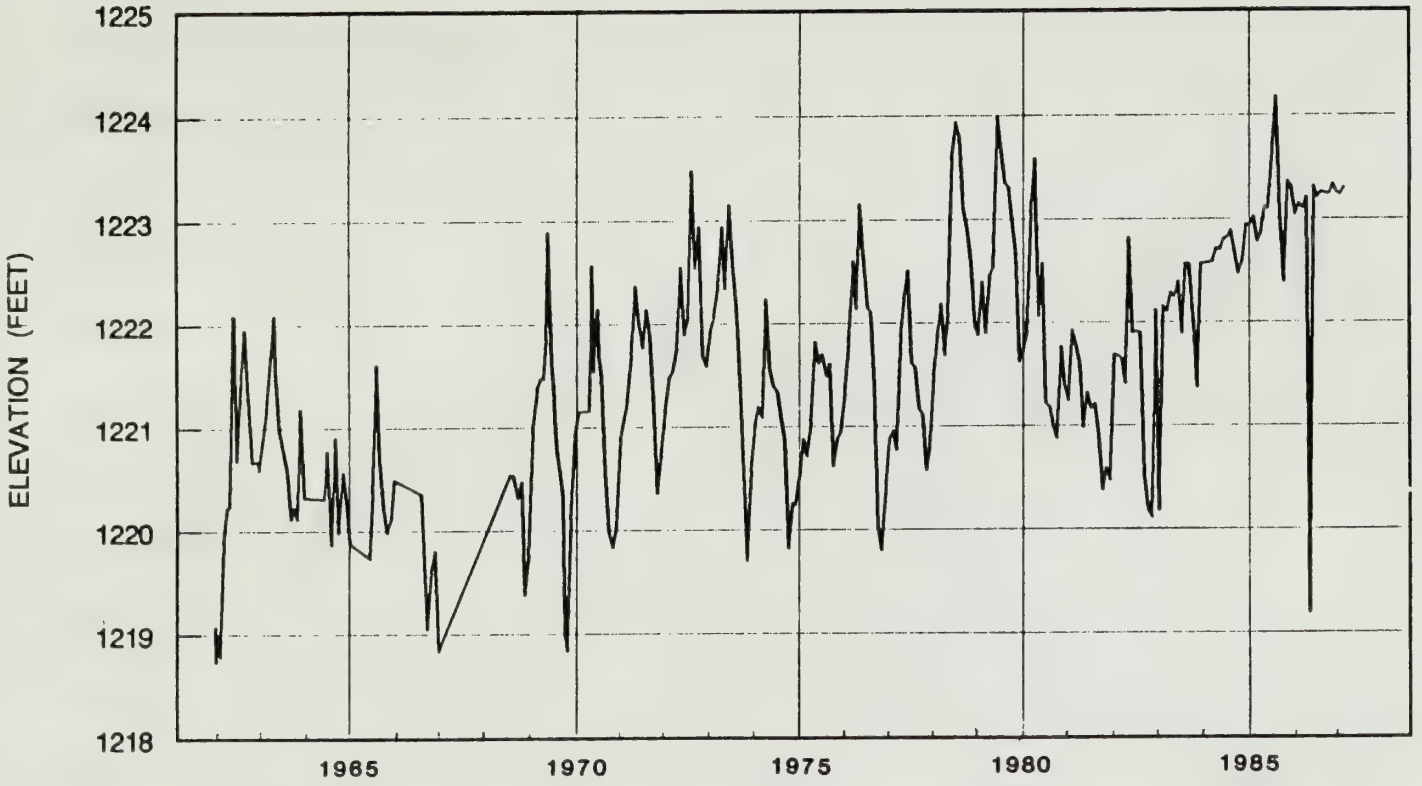


Plate VI.1

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER

GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER, NIOBRARA TOWNSITE # 02
GROUNDWATER PIEZOMETER HYDROGRAPH

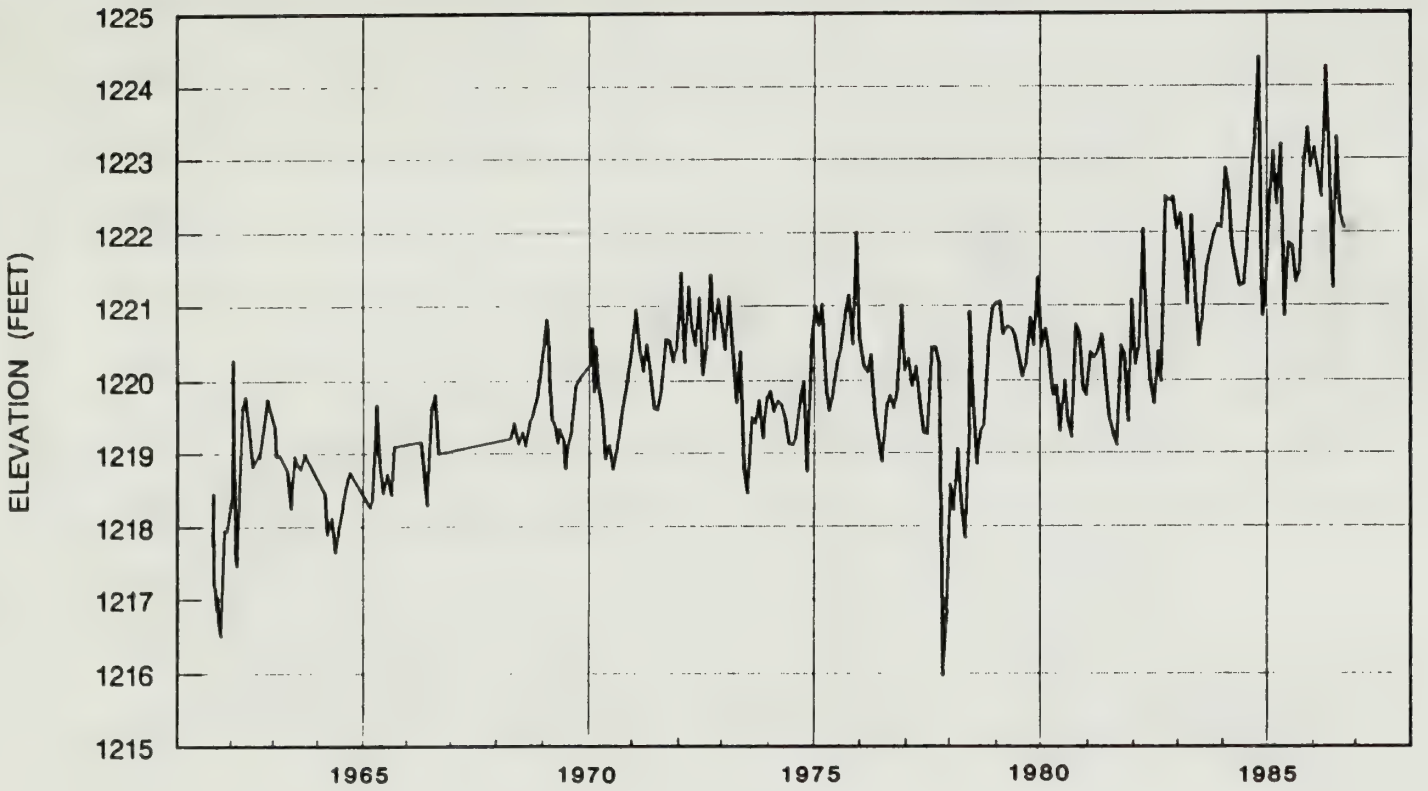


Plate VI.2

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER, NIOBRARA TOWNSITE # 03
GROUNDWATER PIEZOMETER HYDROGRAPH

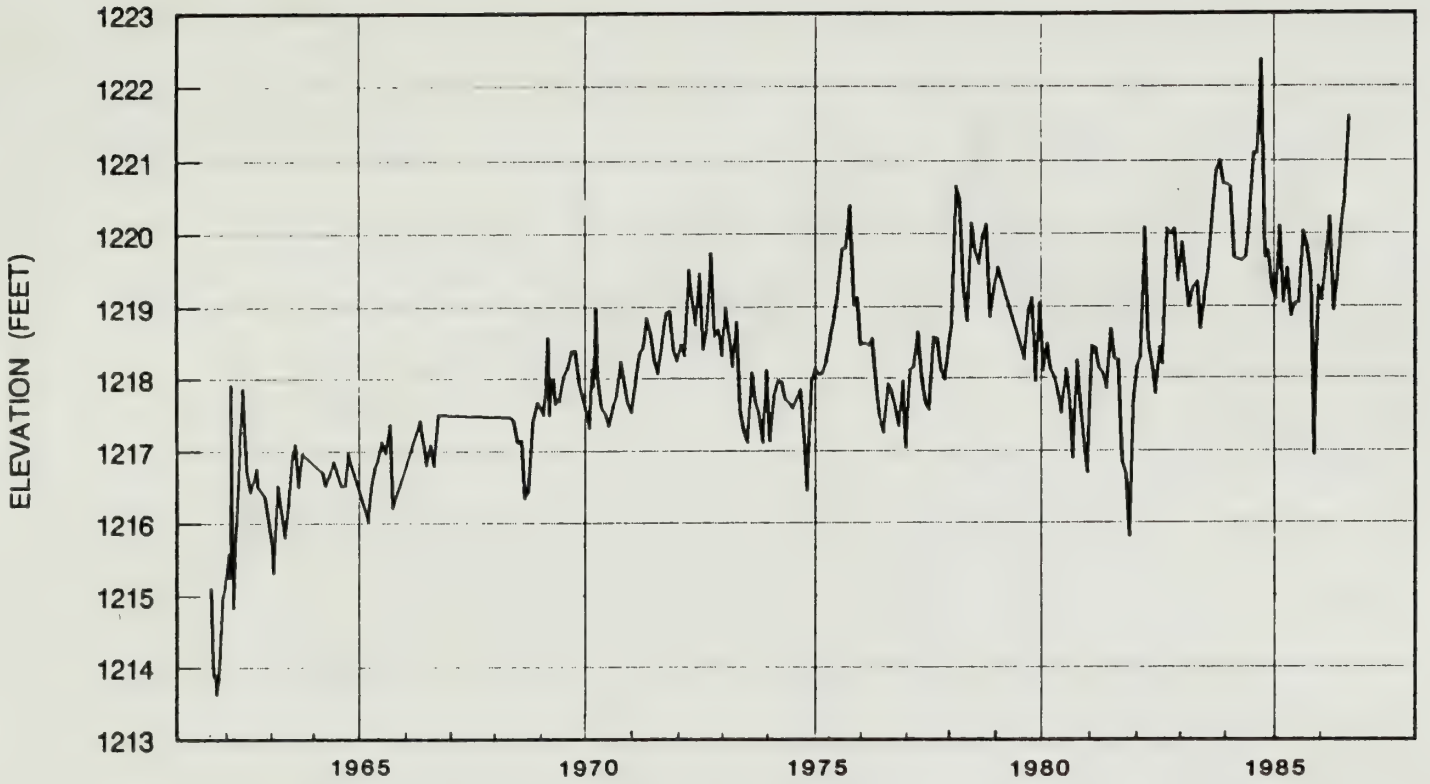


Plate VI.3

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER, NIOBRARA TOWNSITE # 04
GROUNDWATER PIEZOMETER HYDROGRAPH

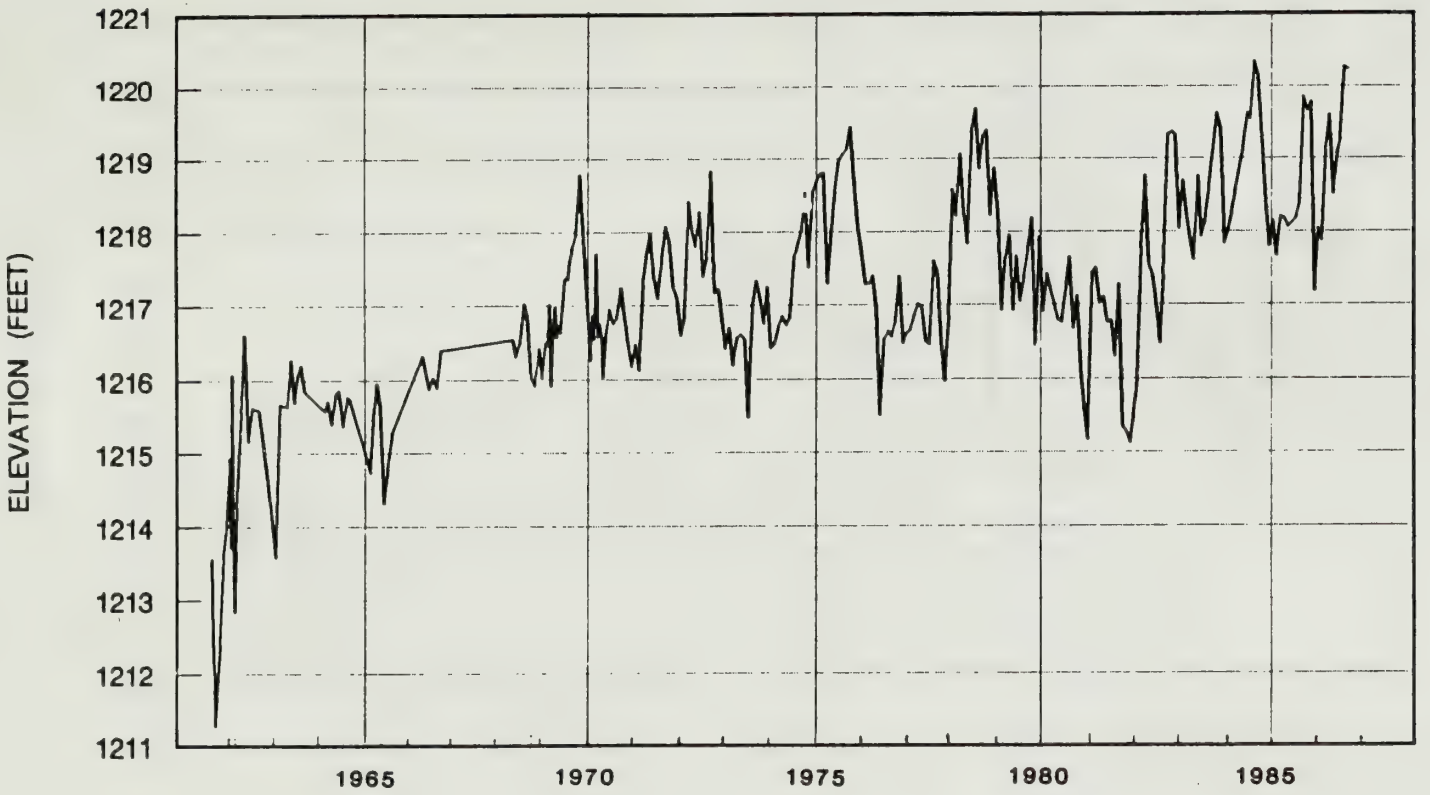


Plate VI.4

NIOBRARA RIVER AGGRADATION STUDY
NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER

WELL NUMBER, NIOBRARA TOWNSITE # 05
GROUNDWATER PIEZOMETER HYDROGRAPH

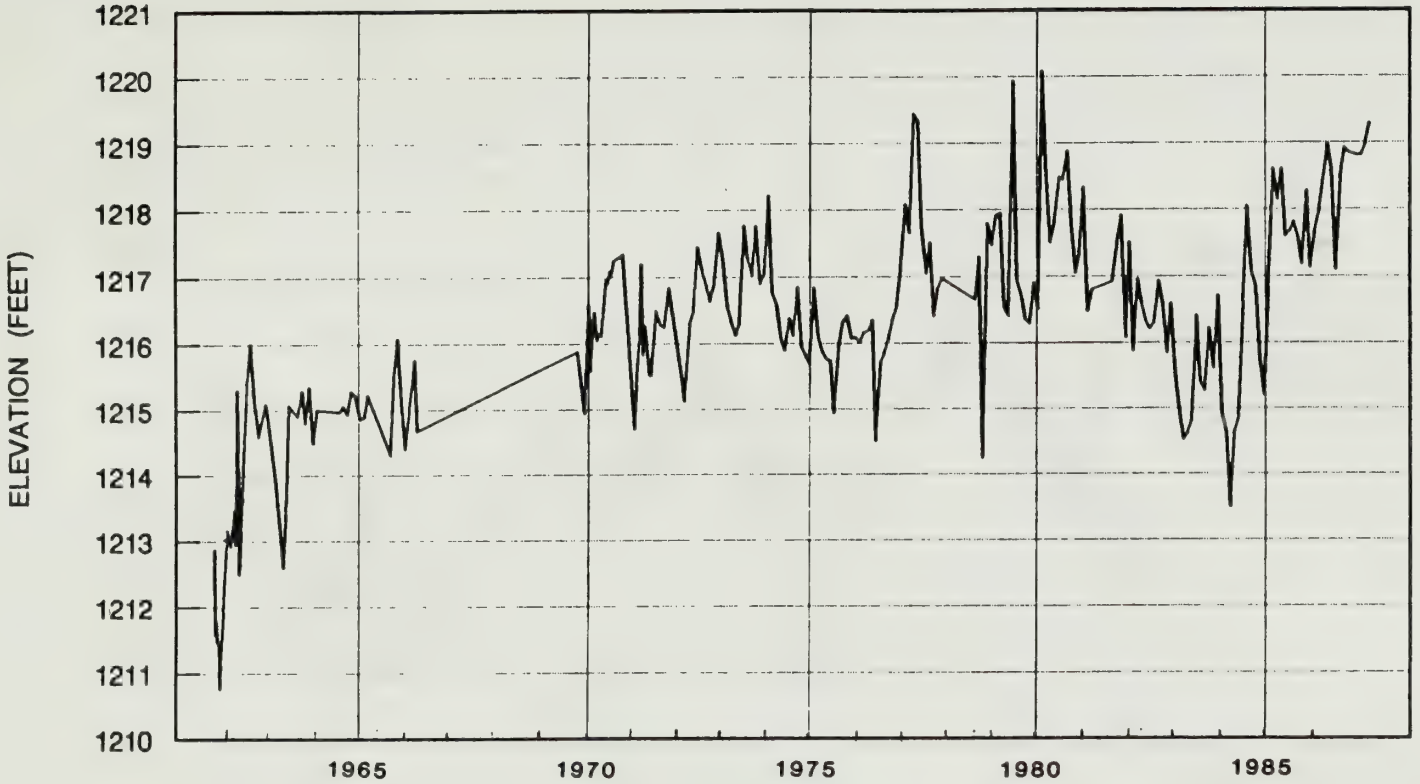


Plate VI.5

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER, NIOBRARA TOWNSITE # 06
GROUNDWATER PIEZOMETER HYDROGRAPH

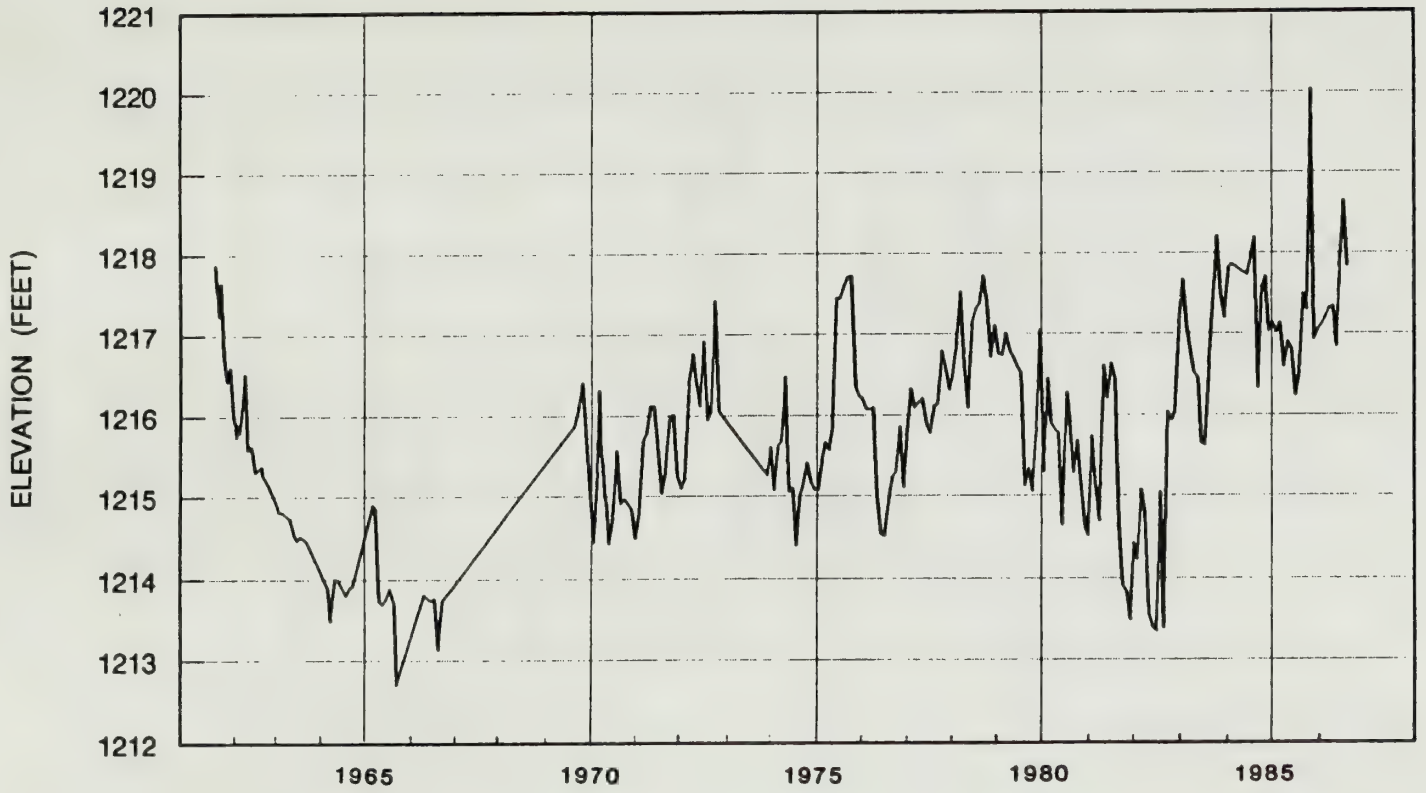


Plate VI.6

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER

WELL NUMBER, NIOBRARA TOWNSITE # 07

GROUNDWATER PIEZOMETER HYDROGRAPH

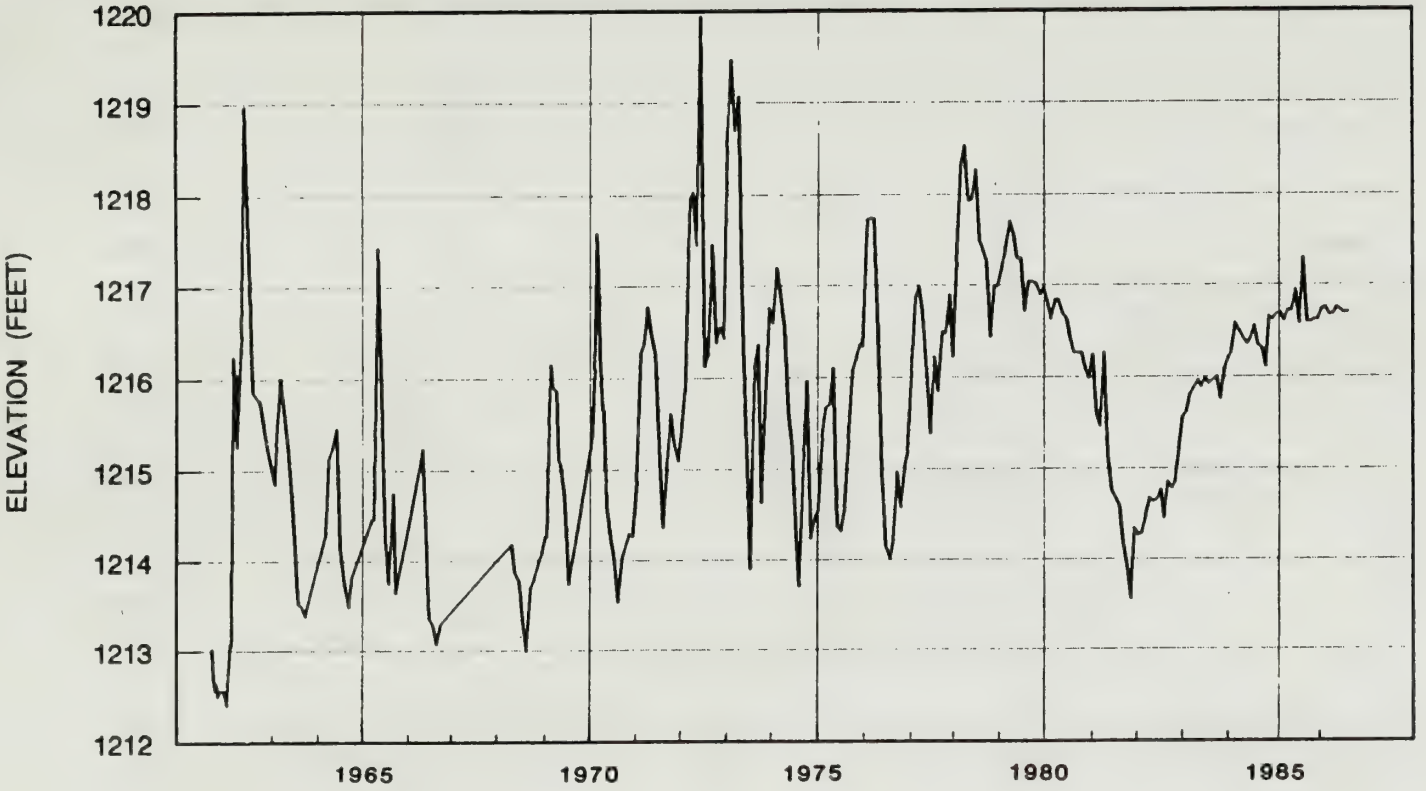


Plate VI.7

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER

GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER

WELL NUMBER, NIOBRARA TOWNSITE # 08
GROUNDWATER PIEZOMETER HYDROGRAPH

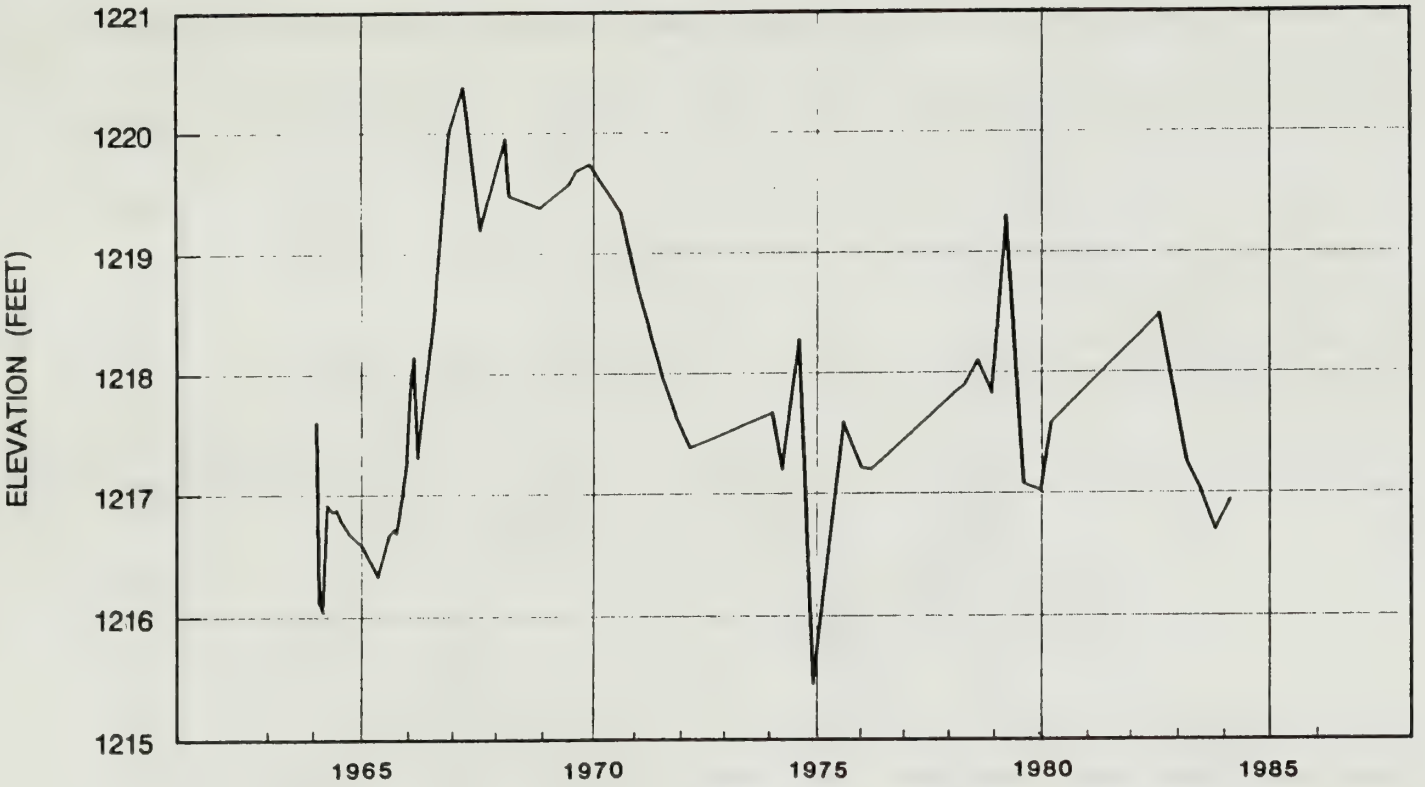


Plate VI.8

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER, NIOBRARA TOWNSITE # 09
GROUNDWATER PIEZOMETER HYDROGRAPH

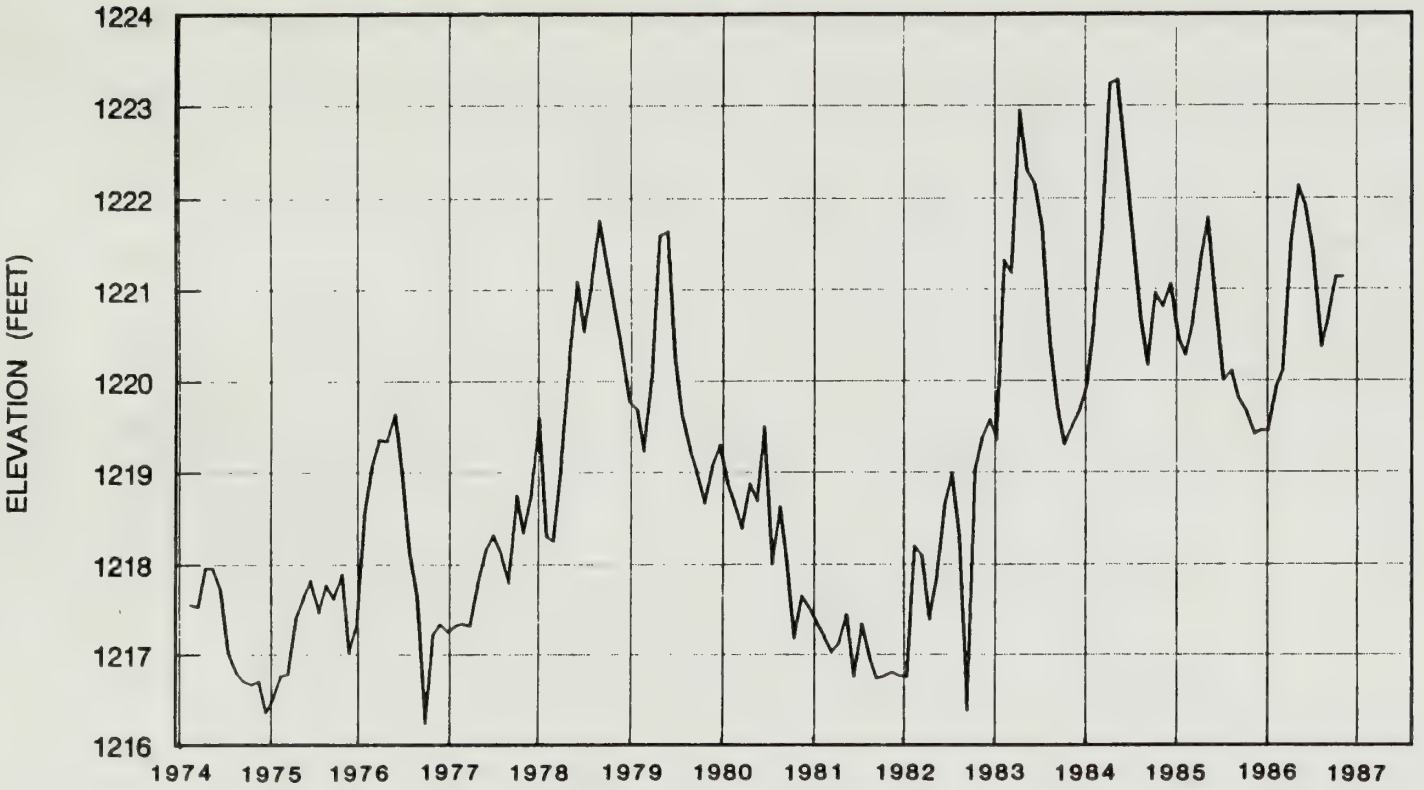


Plate VI.9

NIOBRARA RIVER AGGRADATION STUDY
NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER, NIOBRARA TOWNSITE # 10
GROUNDWATER PIEZOMETER HYDROGRAPH

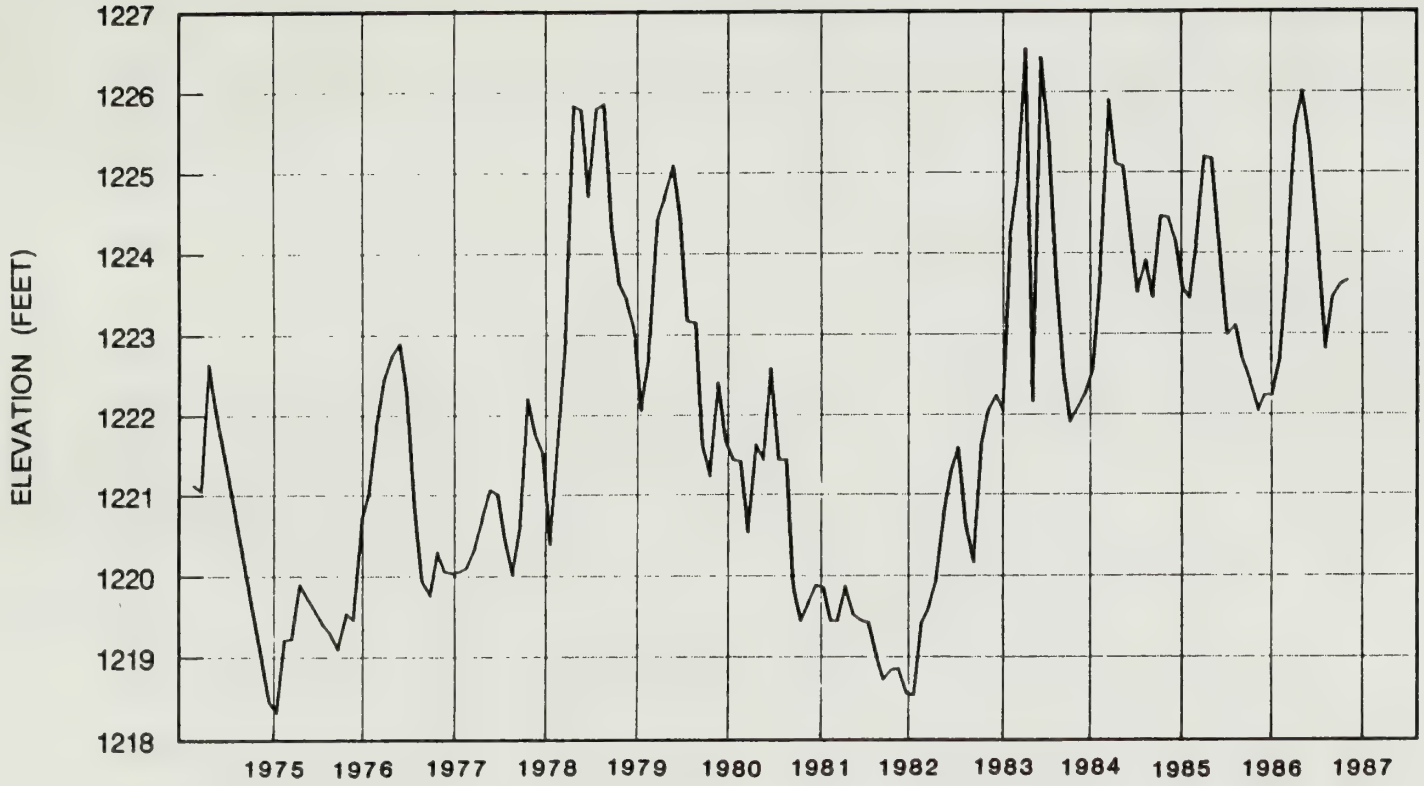


Plate VI.10

NIOBRARA RIVER AGGRADATION STUDY
NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER, NIOBRARA TOWNSITE # 11
GROUNDWATER PIEZOMETER HYDROGRAPH

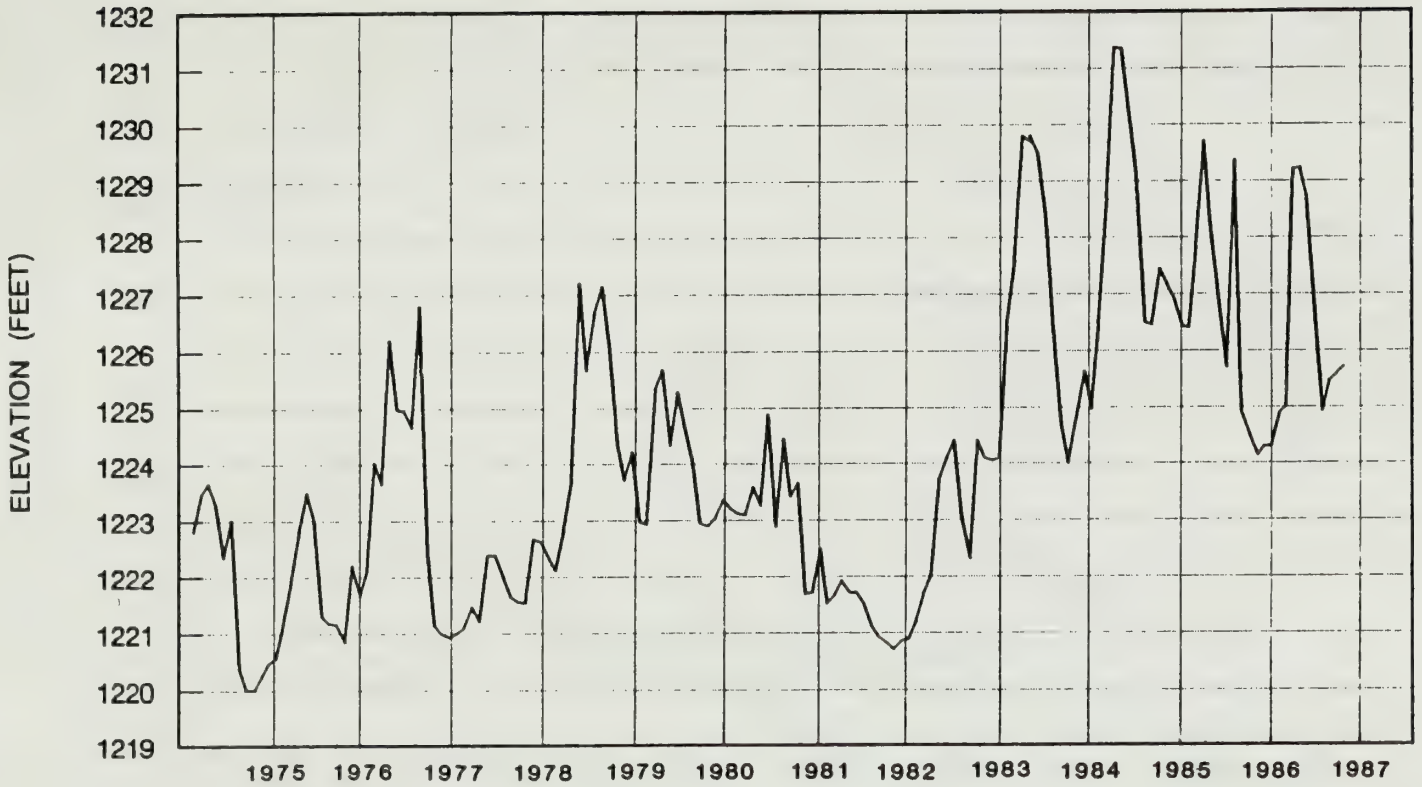


Plate VI.11

NIOBRARA RIVER AGGRADATION STUDY
NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER, NIOBRARA TOWNSITE # 12
GROUNDWATER PIEZOMETER HYDROGRAPH

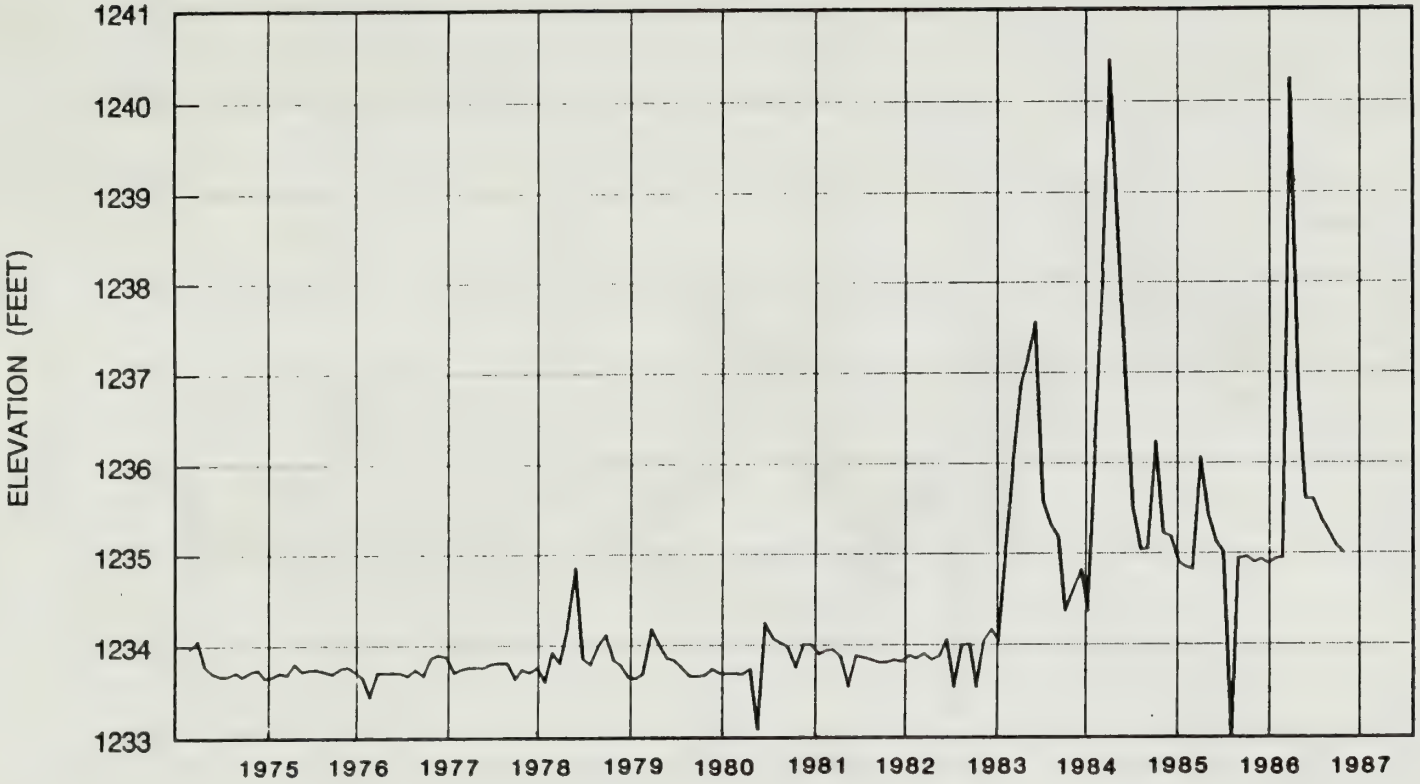


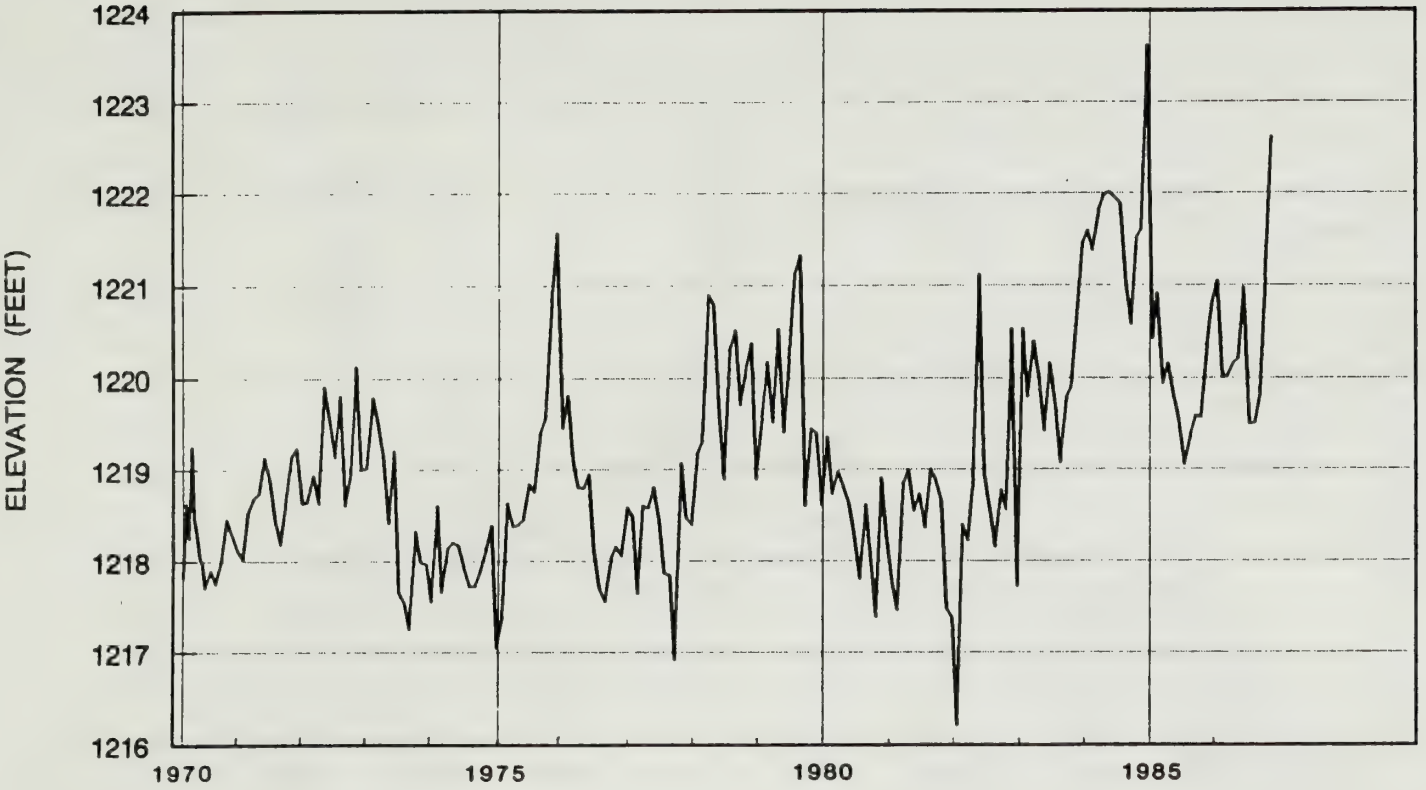
Plate VI.12

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

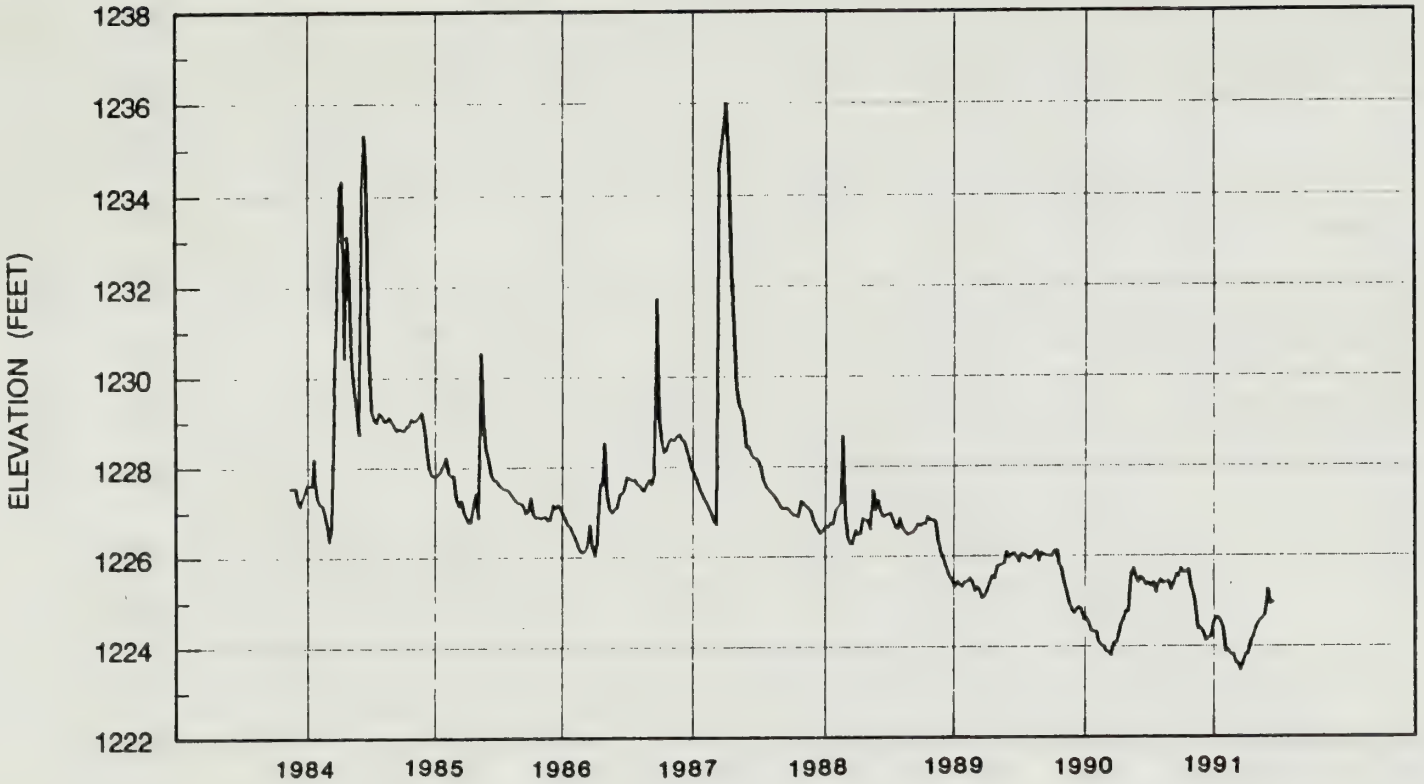
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER, USGS # 32-6-8dd
GROUNDWATER PIEZOMETER HYDROGRAPH



NIOBRARA RIVER AGGRADATION STUDY
NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER
WELL NUMBER DH-83-01
GROUNDWATER PIEZOMETER HYDROGRAPH



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER
WELL NUMBER DH-83-02
GROUNDWATER PIEZOMETER HYDROGRAPH

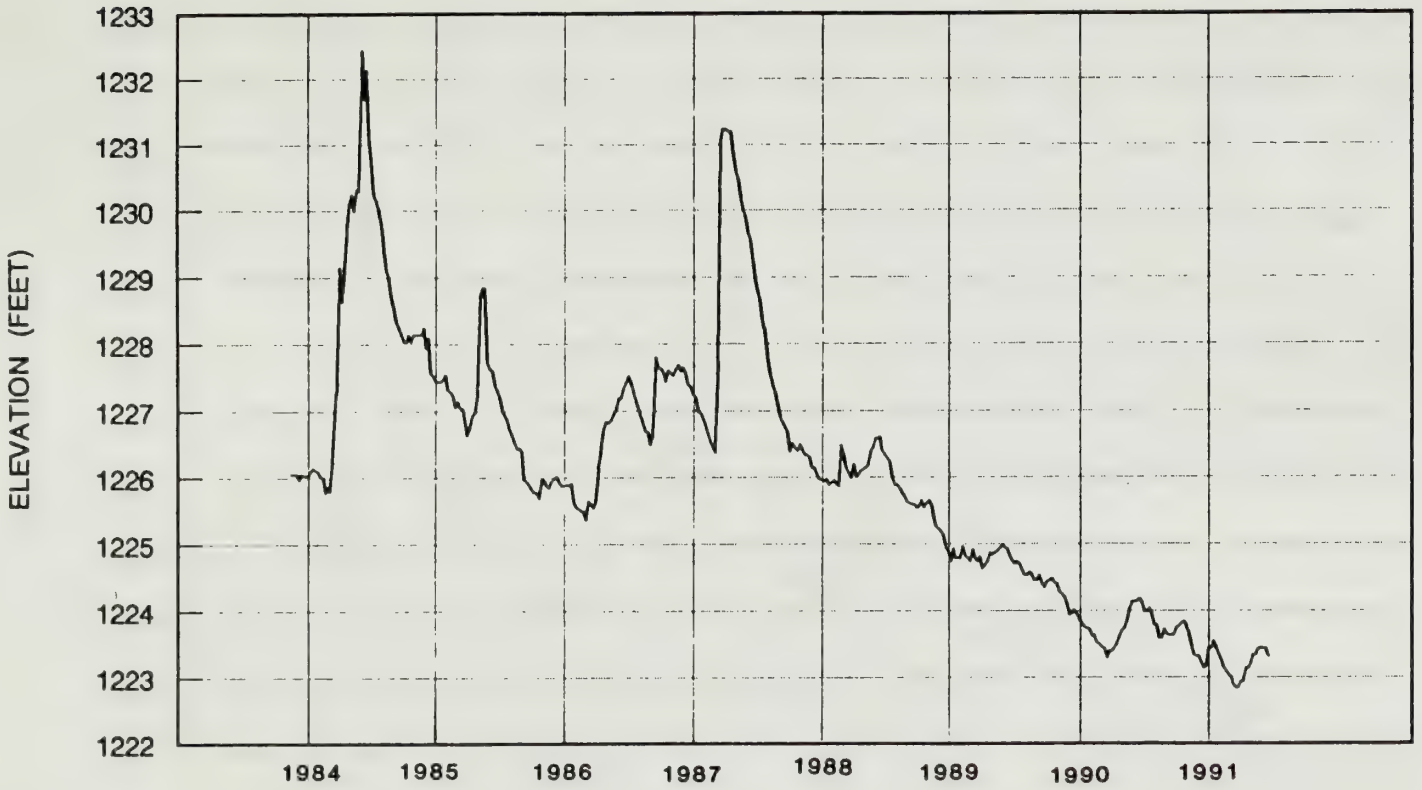


Plate VI.15

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER
WELL NUMBER DH-83-03
GROUNDWATER PIEZOMETER HYDROGRAPH

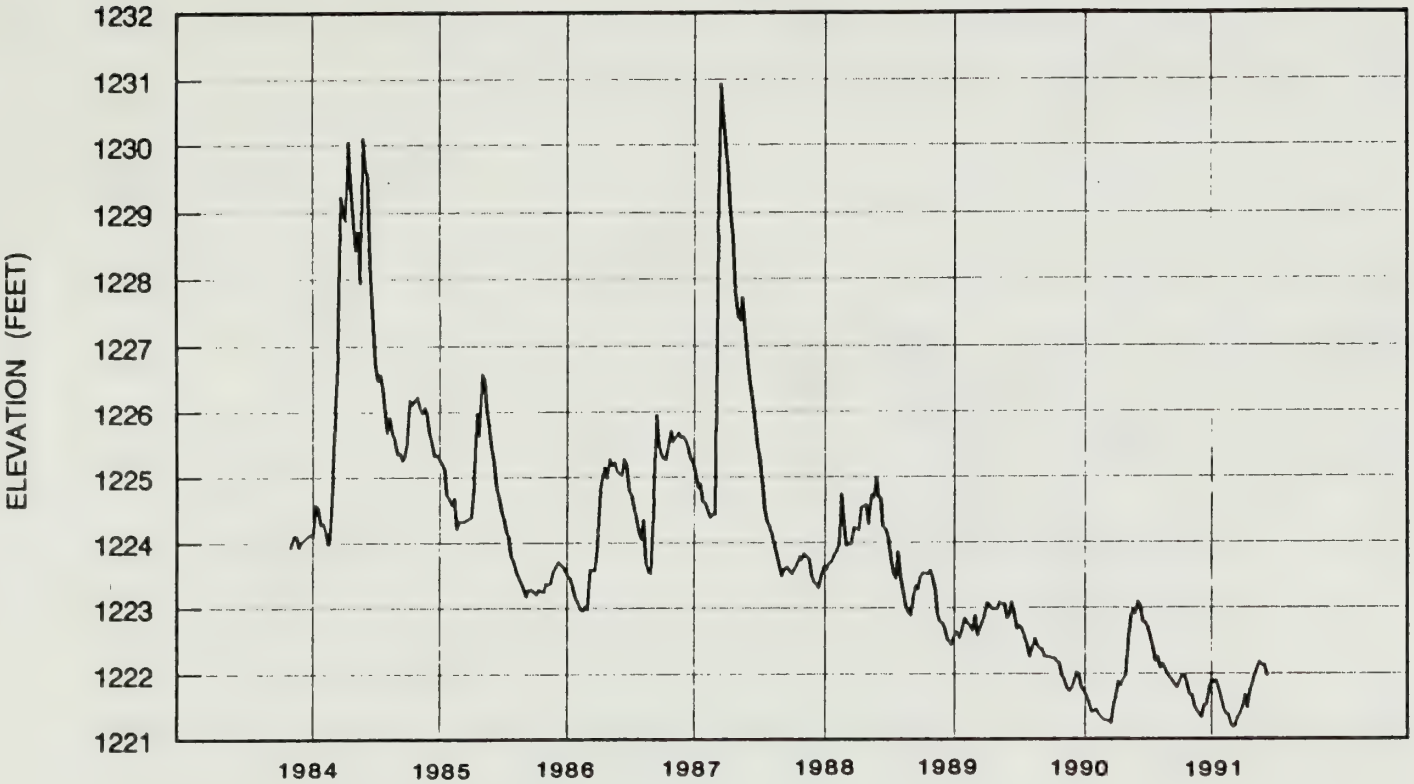


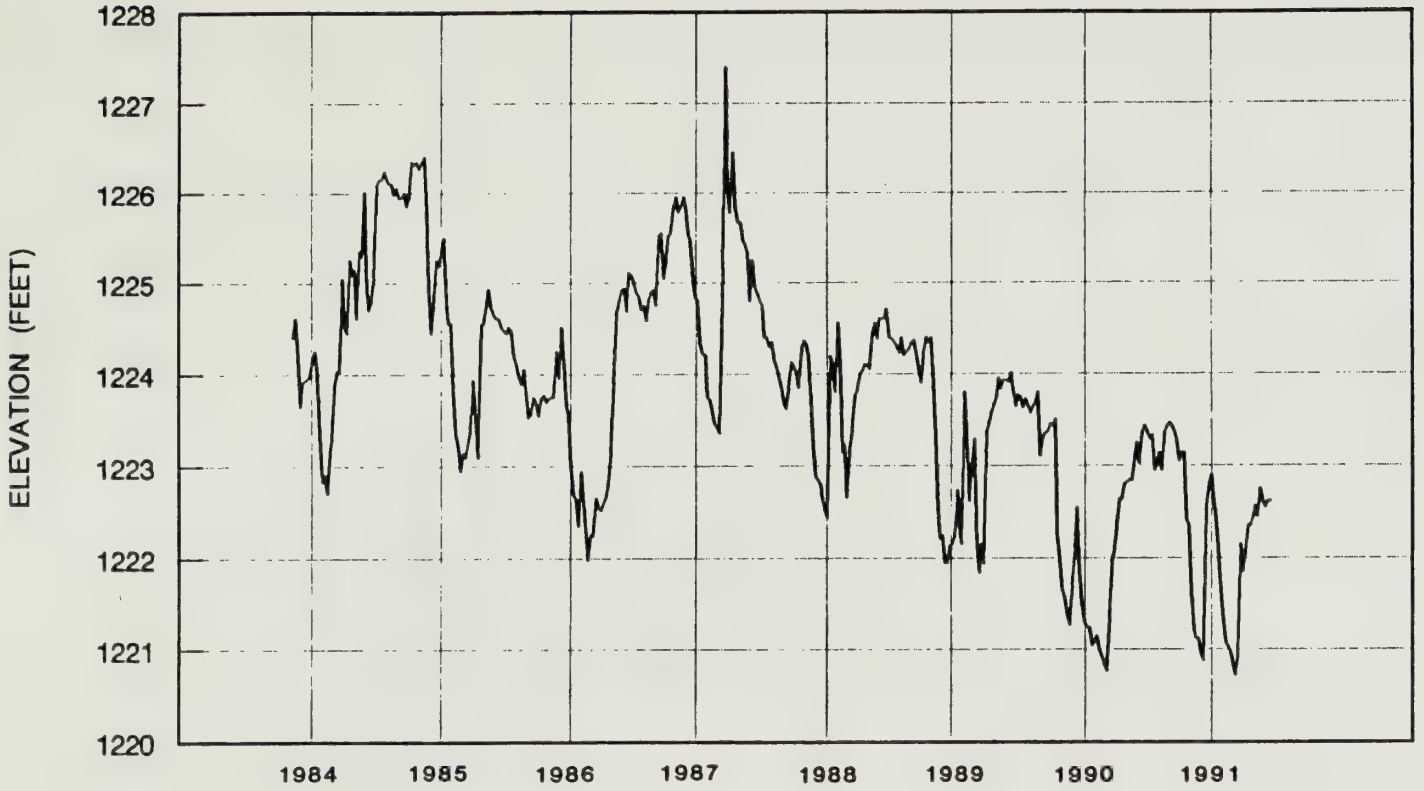
Plate VI.16

NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MISSOURI RIVER
WELL NUMBER DH-83-03A
GROUNDWATER PIEZOMETER HYDROGRAPH



NIOBRARA RIVER AGGRADATION STUDY

MISSOURI RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER DH-83-04
GROUNDWATER PIEZOMETER HYDROGRAPH

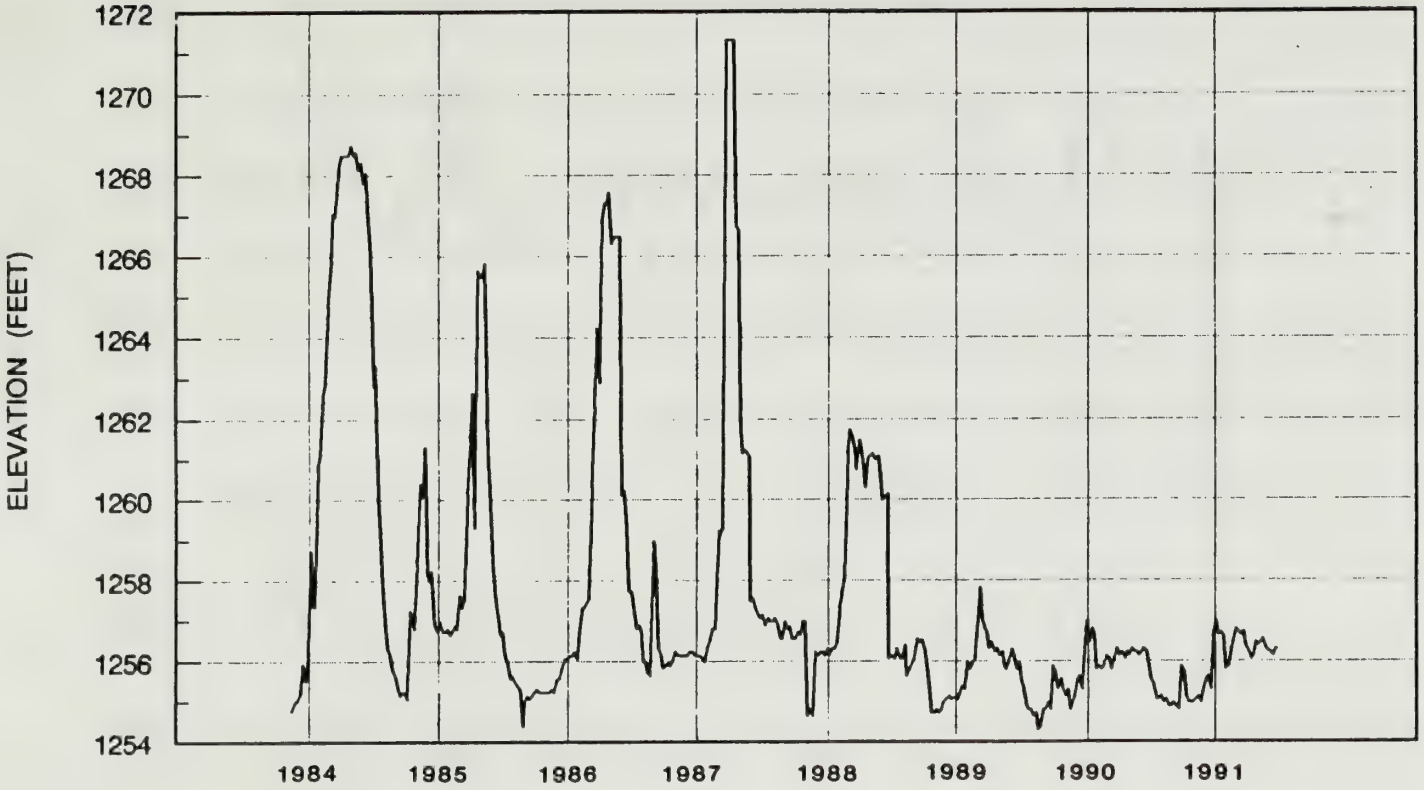


Plate VI.18

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER DH-83-05
GROUNDWATER PIEZOMETER HYDROGRAPH

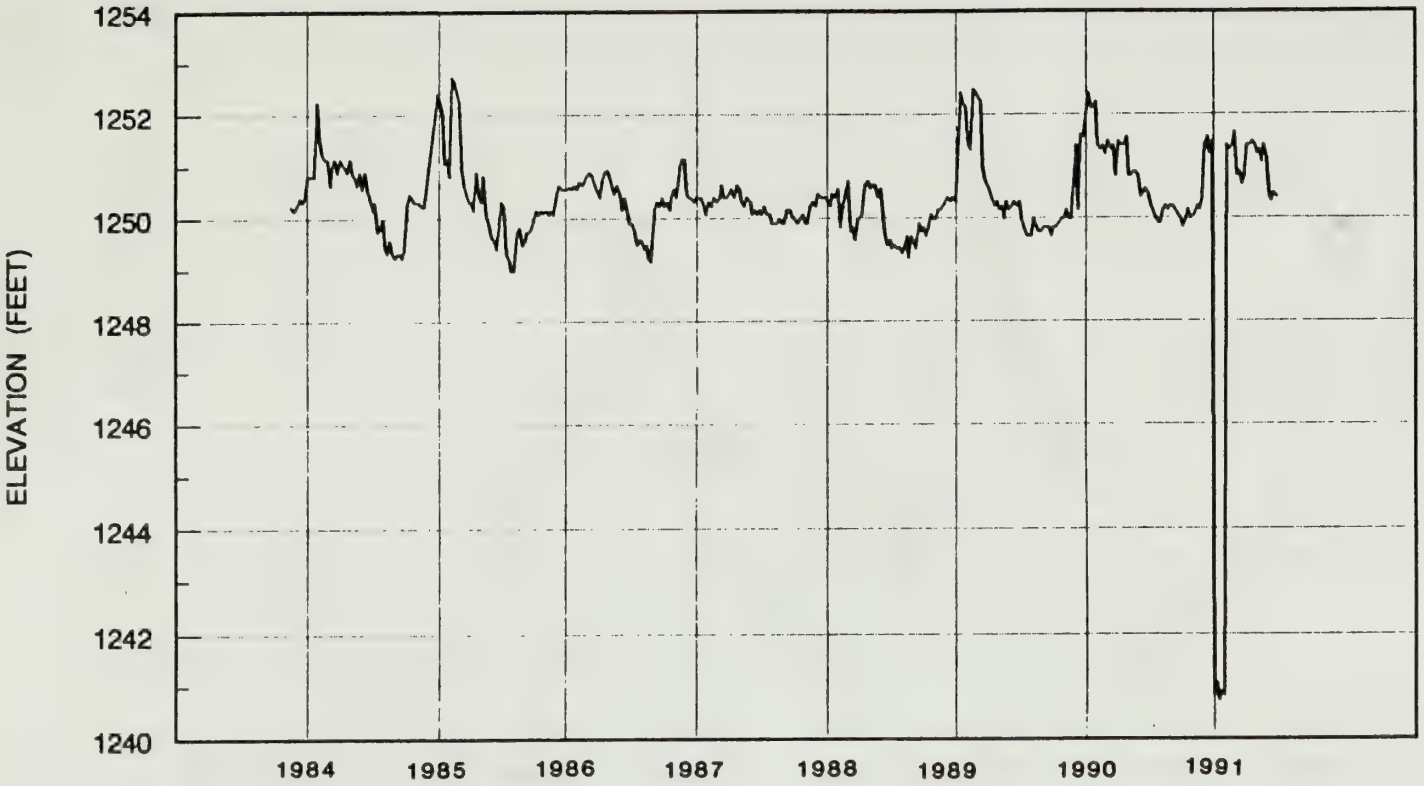


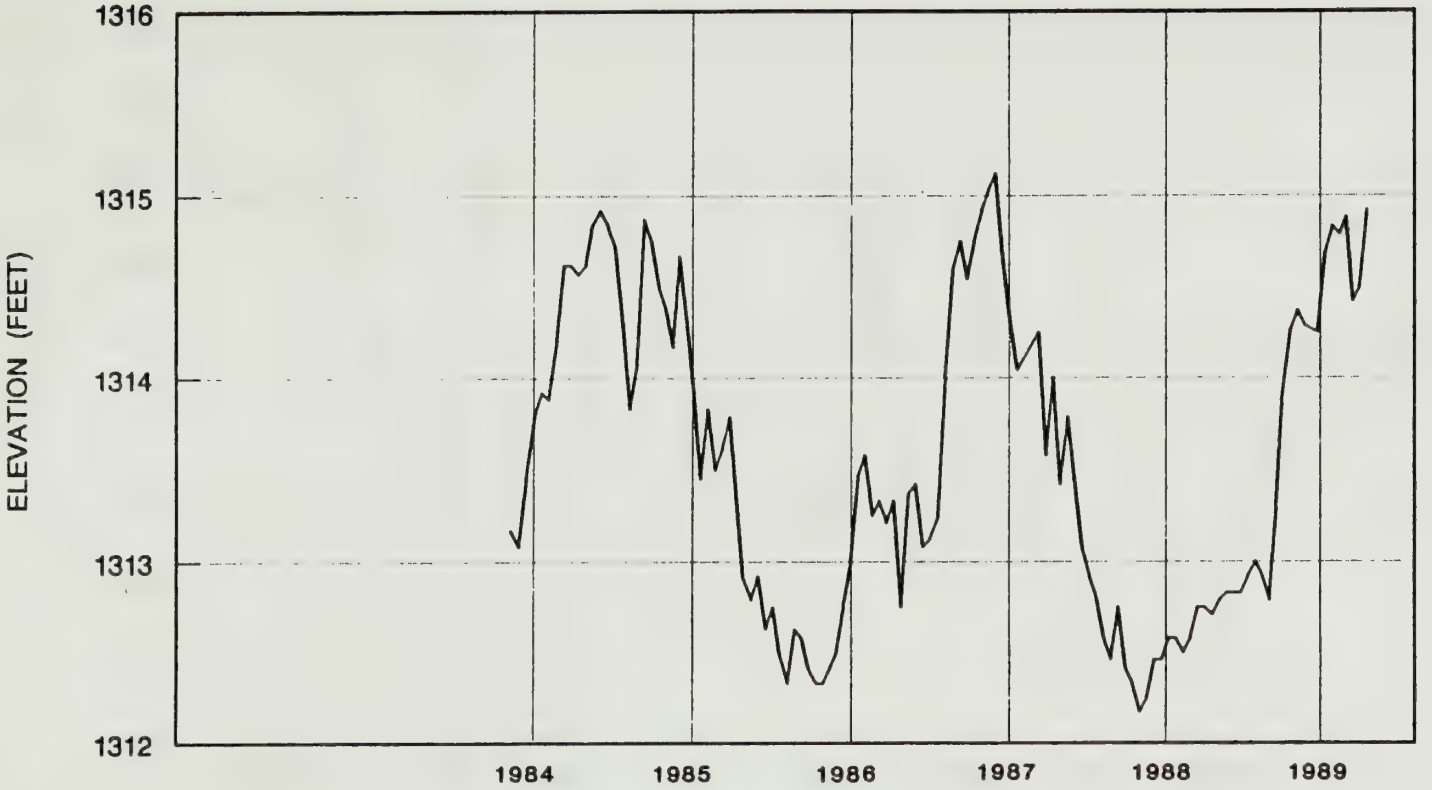
Plate VI.19

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER DH-83-06
GROUNDWATER PIEZOMETER HYDROGRAPH



NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER DH-83-07
GROUNDWATER PIEZOMETER HYDROGRAPH

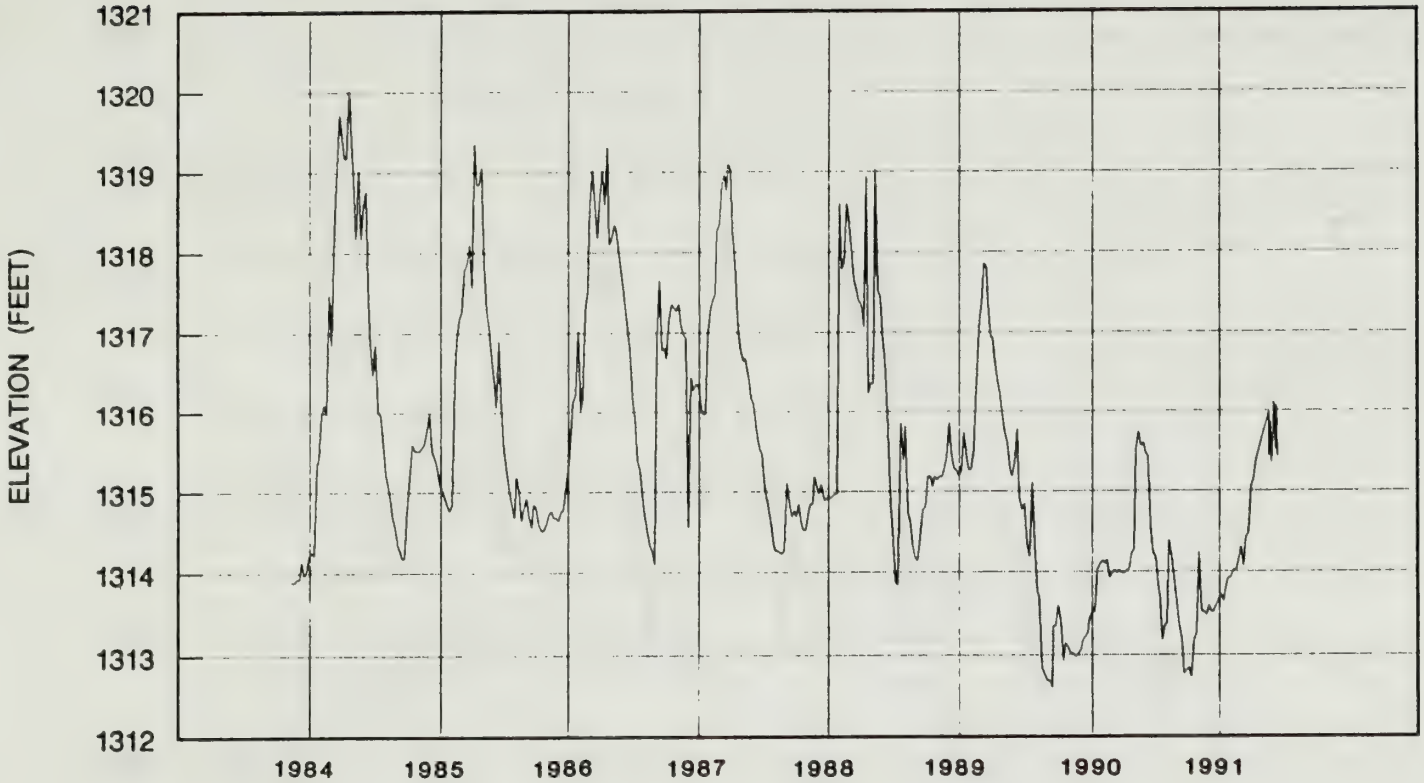


Plate VI.21

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

NIOBRARA RIVER
WELL NUMBER DH-83-08
GROUNDWATER PIEZOMETER HYDROGRAPH

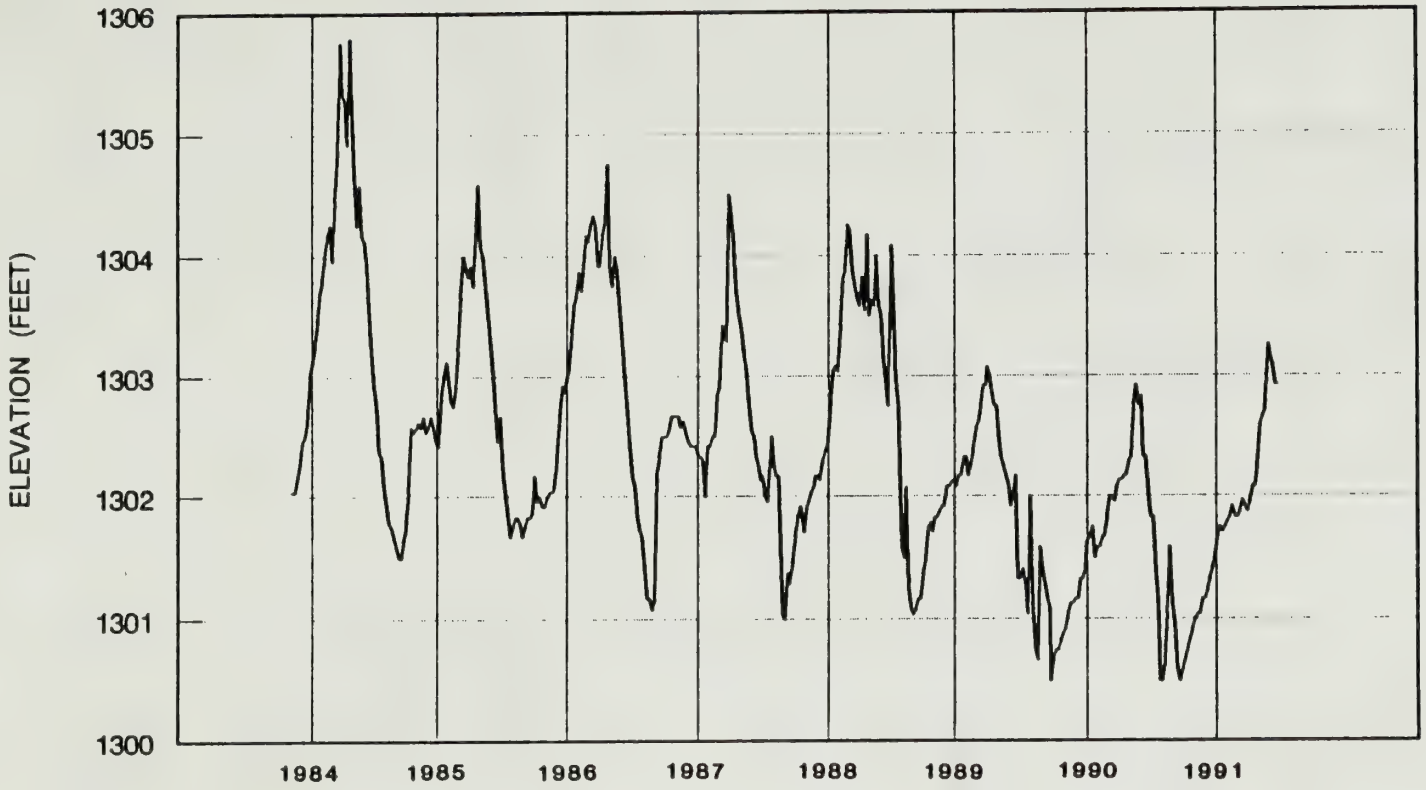


Plate VI.22

NIOBRARA RIVER AGGRADATION STUDY

NIOBRARA RIVER
GROUNDWATER PIEZOMETER HYDROGRAPH

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1991

MRD SEDIMENT MEMORANDA

NO.	TITLE	AUTHOR	DATE
1	Sedimentation in Kanopolis Reservoir	A. L. Hill A. M. Gow	1955
2	1954 Aggradation Surveys in Garrison Reservoir	F. S. Witzigman I. Shepherdson	1955
3	Degradation Below Garrison Dam	F. S. Witzigman	1957
4	Observations of Rate of Change in Sediment Concentration with Respect to Changing Hydraulic Conditions at the Head of a Reservoir	F. S. Witzigman	1955
5	Deposition in Fort Randall	R. H. Livesey	1955
6	Determination of Location and Rate of growth of Delta Formations	L. C. Fowler	1957
7	Papillion Creek Site 11 Sedimentation Studies Area-Capacity Report	J. W. Garrison	1989
8	Sedimentation in Fort Peck Reservoir, 1937-1987	L. A. Timp	1989
9	Lake Francis Case Aggradation Study (Including White River 1953-1986	Stanley Consultants (In association with Missman, Stanley and Associates)	1989
10	Cherry Creek Lake Sedimentation Studies Area-Capacity Report -1988	L. J. Morong	1989
11	Big Bend Project Bad River Aggradation Assessment and Data Compilation	J. W. Garrison	1991
12	Sedimentation Near the Confluof the Missouri and Niobrara Rivers (1954 to 1990)	Resource Consultants & Engineers, Inc.	1992